United States
Environmental Protection
Agency

Air Pollution Training Institute (APTI)
Mail Drop E14301
Research Triangle Park, NC 27711

September 2004

Air

Preparation of Fine Particulate Emission Inventories

Student Workbook

APTI Course 419B

How to Use this Workbook

This workbook is to be used during classroom instruction, and telecourse sessions. This workbook contains the slides used by the presenter as well as space for taking notes.

The goal of the presentation is to go over many of the topics presented in the Student Manual. At times during the presentation, content has been condensed and at other times expanded with further explanation. This workbook will match the slide show exactly.

The Student Manual will contain the instructional objectives and detailed materials for each of the seven chapters. It would be useful to have the Student Manual with you during the presentation as references may me made to it. In addition, some graphics might be hard to read during the presentation, but all graphics used in the presentation can be found in the Student Manual.

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Course Description

APTI 419B: *Preparation of Fine Particulate Emission Inventories* is a two-day, resident instructional course designed to present an advanced view of all major, practical aspects of developing an emission inventory for fine particulate matter. The course is intended primarily for employees that have a working knowledge of emission inventory terminology and techniques. The course focuses on the principal stationary nonpoint area and nonroad mobile source categories emitting PM fine particles. For select categories, the course provides a brief summary of how emissions are estimated for EPA's National Emissions Inventory (NEI), and how state/local/tribal agencies can improve upon those estimates. Case studies are used to provide real-world examples of how state or lo9cal agencies collected their own data to prepare inventories that are improvement to the NEI methods. The lessons include information on an overview of fine PM, an overview of the NEI, onroad mobile inventory development, onroad mobile inventory development, point source inventory development, area sources, fugitive dust area sources, combustion area sources, and other related topics.

The course is taught at an instructional level equivalent to that of an advanced, undergraduate university course. The Air Pollution Training Institute curriculum recommends APTI 419B: *Preparation of Fine Particulate Emission Inventories* as an advanced course for all areas of study. The student should have minimally completed a college-level education and APTI Course SI:419A – *Introduction to Emission Inventories* or have a minimum of six months of applicable work experience.

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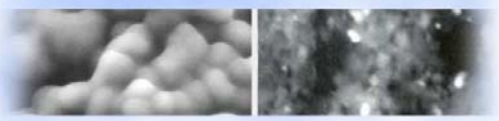
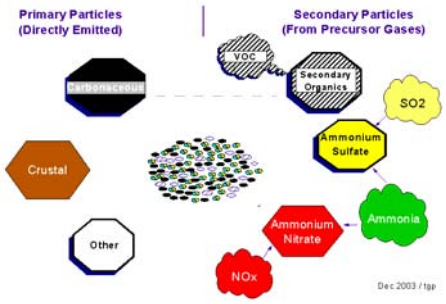
Preparation of Fine Particulate Emissions Inventories

Chapter 1 - PM $_{2.5}$ Overview



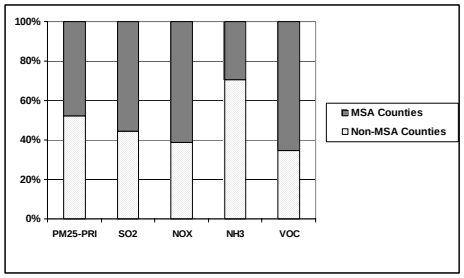
$PM_{2.5}$ In Ambient Air - A Complex Mixture



Urban PM Sites

- Eastern U.S. data is very homogenous
- Comprised mostly of carbon
- Ammonium and sulfate components combined are comparable to carbon
- Crustal component is very small

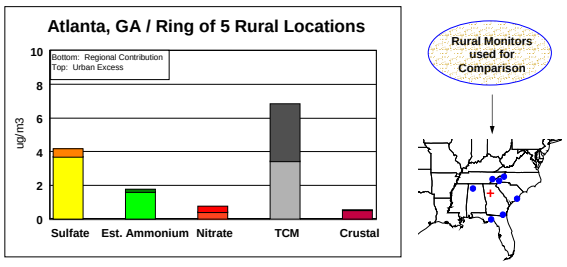
MSA to Non MSA Comparison of PM Emissions



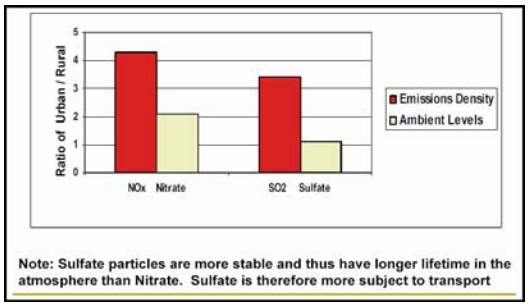
Comparison of Urban and Rural Data

- More sulfate than carbon in non-urban sites
- Sulfate concentration slightly higher in urban areas
- Carbon concentrations substantially higher in urban areas
- Conclusions
  - Sulfate is a regional problem
  - Carbon has a regional component with urban excess
- Urban Excess definition

Example of "Urban Excess"



Comparison of Urban~Rural Ratios



Note: Sulfate particles are more stable and thus have longer lifetime in the atmosphere than Nitrate. Sulfate is therefore more subject to transport

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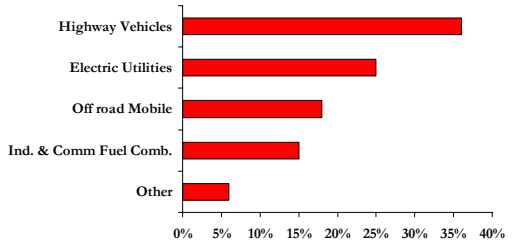
National NOx Emissions



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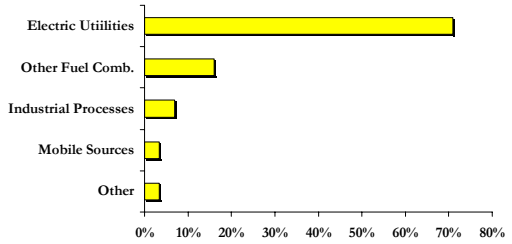
SO2 National Emissions



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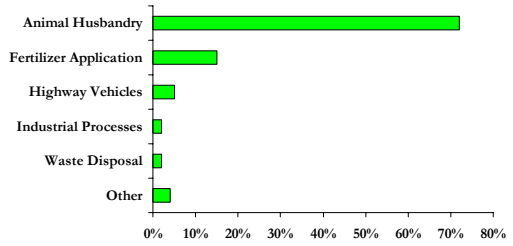
NH3 National Emissions



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Crustal Material

- Main Sources:
  - Unpaved roads
  - Agricultural tilling
  - Construction
  - Wind-blown dust
  - Fly ash (less significant)

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Crustal Material (cont.)

- Huge Disparity Between EI & Ambient Data
  - Ambient Data
    - < 1 ug/m3 in most of US
    - Exception: > 1 ug/m3 in much of Southwest
    - Emissions: 2.5M TPY (comparable to Carbon Emissions)

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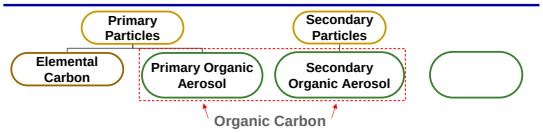
Crustal Material (cont.)

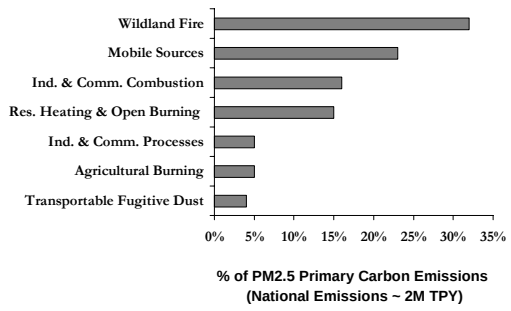
- Fugitive Dust has low "Transportable Fraction
- Crustal materials are a relatively small part of PM2.5 in the ambient air
- Fugitive dust is released near the ground and surface features often capture the dust near its source
- As much as 50-90% may be captured locally

Carbon Particles: Composition & Terminology



- Primary Particles
  - Elemental (Black) Carbon
  - Primary Organic Aerosol (POA)
  - Primary Carbon = EC (BC) + Primary Organic Aerosol (POA)

Primary Carbon in PM2.5



POA & EC Characteristics of Primary Carbon Emissions

Category	Ratio of organic carbon mass* to elemental carbon mass (average)	Potential range of ratios
Forest Fires	9.9	6 – 28
Managed Burning	12	6 – 28
Agricultural Burning	12	2.5 – 12
Open Burning - Debris	9.9	
Non-road Diesel Engines & Vehicles	**0.4**	**0.4 – 3**
On-road Diesel Vehicles	**0.4**	**0.4 – 3**
Trains, Ships, Planes	**0.4**	**0.4 – 25**
Non-road Gas Engines & Vehicles	14	0.25– 14
On-road Gas Vehicles	4.2	0.25 – 14
Fugitive Dust - Roads	22	3 – 65
Woodstoves	7.4	3 – 50
Fireplaces	7.4	3 – 50
Residential Heating - Other	26	
Commercial Cooking	111	13 – 111

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Primary Organic Aerosols (POA)

- Certain organic carbon excluded
- Organic carbon matter = primary organic aerosol (POA).
- The OC to POA multiplier for “fresh” POA in the emissions is usually estimated
- Particles “age” through oxidation.
- A different “multiplier” is applied to the POA by the chemical transport models to account for the “aging”

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Primary Organic Aerosols (cont.)

- Models only apply the additional multiplier to the POA, not the EC or SOA
- Multiplier is not related to the model’s estimate of secondary organic aerosol formed in the atmosphere from precursor gases
- Only accounts for further oxidation of primary particle emissions as the aerosol “ages”
- Transport models contain a separate module to simulate the amount of secondary organic carbon formed in the atmosphere from precursor

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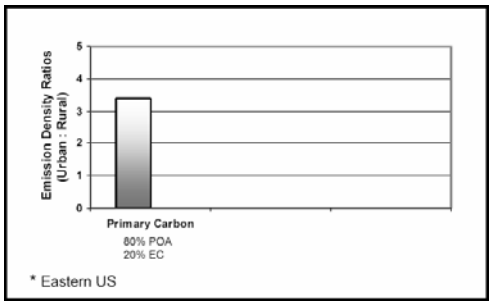
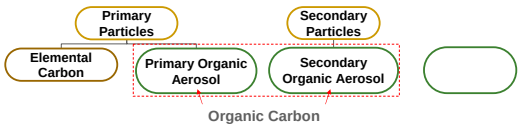
Primary Organic Aerosols (cont.)

- The derivation of a multiplier for ambient OC is much more complicated
- Use of a single multiplier introduces error
- A multiplier of 1.4 to 2.4 is often used for ambient data
- No agreed upon standard adjustment

Primary Carbon Emissions Emission Density Ratios



Carbon Particles: Composition & Terminology



- Primary Particles
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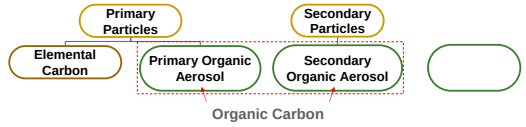
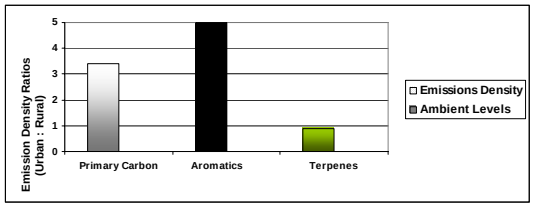
Carbon Particles: Composition & Terminology (cont.)



- Secondary Particles
  - Secondary Organic Aerosol (SOA)
- Organic Carbon = POA & Secondary Organic Aerosols

Comparison of Emission Density Ratios



	80% POA 20% EC	70% Mobile	Biogenic
Emissions:	**2.2M tpy (Ann)**	**3.7 M tpy (Ann)**	**.35 M tpy (July)**

* Eastern US

Summary of Important PM2.5 Source Categories

DIRECT EMISSIONS

Combustion [a, b]
- **Open Burning (all types)**
- **Non-Road & On-Road Mobile**
- **Residential Wood Burning**
- **Wildfires**
- Power Gen
- Boilers (Oil, Gas, Coal)
- Boilers (Wood)

Crustal / Metals [a]
- **Fugitive Dust**
- Mineral Prod Ind
- Ferrous Metals

PRECURSOR EMISSIONS

SO2 [c]
- **Power Gen (Coal)**
- **Boilers (Coal)**
- Power Gen (Oil)
- Boilers (Oil)
- Industrial Processes

NOx
- **On-Road Mobile (Gas, Diesel)**
- **Power Gen (Coal)**
- **Non-Road Mobile (Diesel)**
- **Boilers (Gas, Coal)**
- Residential (Gas, Oil)
- Industrial Processes

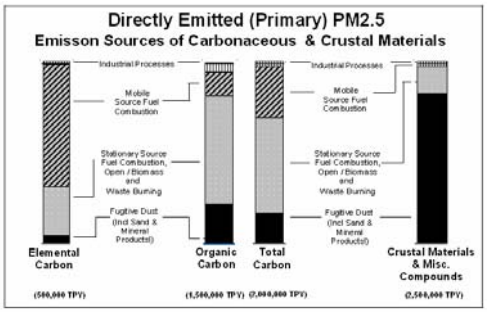
NH3
- **On-Road Mobile**
- **Animal Husbandry**
- **Fertilizer Application**
- Wastewater Treatment
- Boilers

VOC [d]
- **Biogenics**
- **Solvent use**
- **On-Road (Gas)**
- Storage and Transport
- Residential Wood
- Petrochemical Industry
- Waste Disposal

a Includes primary organic particles, elemental carbon and condensible organic particles; also some flyash
b Impact of carbonaceous emissions on ambient PM 5 to 10 times more than crustal emissions impact
c Includes SO2 and SO3and H2SO4 condensible inorganics
d Contributes to formation of secondary organic aerosols

NOTE: Categories in **BOLD** are most important nationally. Their relative importance varies among and between urban and rural areas.

PM2.5 Primary Emissions Sources - Summary



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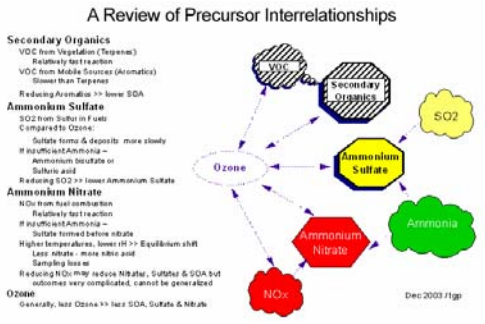
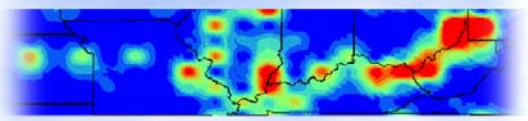


Preparation of Fine Particulate Emissions Inventories

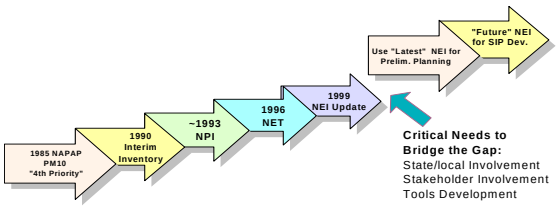
Chapter 2 - The National Emissions Inventory and Emission Inventory Tools



Information Included in the NEI

- National tabulation of emissions of PM2.5, SO2, NOx, Ammonia, and VOC
  - Point sources by lat-long: 52,000 facilities, each containing multiple emission points
    - Over 4,500 types of processes represented
  - Area & Mobile by County
    - 400 categories of Highway & Non-Road Mobile
    - Over 300 categories of Area sources
- Annual emissions, start/end dates, stack parameters
- Also, in the NEI
  - HAP emissions for over 6,000 types of processes

Evolution of EPA's National Emission Inventory

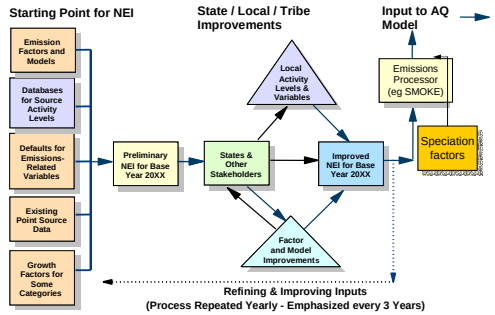


NAPAP - National Acidic Precipitation Assessment Program
NPI National Particulate Inventory
NET National Emission Trends Inventory
NEI Merger of NET and Nat'l Toxics EI

Wildfires in the National Emission Inventory

- Will be included as point sources
- Data on location, and start and stop dates
- Currently handled as areas sources
  - Allocated by county and season
- Impossible to determine impact under the current approach

NEI Development ~ Cooperative, Iterative



Inventory Preparation Tools

- Emission Factors & Activity Data
  - www.epa.gov/ttn/chief
  - (~ 20,000 factors in FIRE)
  - Processes vary over time ~ Factor representiveness issue

Inventory Preparation Tools (cont.)

- Emissions Models
  - TANKS
  - NONROAD
  - Others

Inventory Preparation Tools (cont.)

- Spatial Characterization & Locator Aids
  - GIS
  - GPS
  - Satellites
- Emissions Processing, including Speciation

Overview of Emissions Processing

- Processors include:
  - SMOKE, EPM
- Processor output
  - Gridded, hourly emissions file
  - Speciation of Primary Emissions (EC, Organics, SO4, Nitrates)
  - Model-ready
- Processor inputs
  - Annual, county-level area source EI
  - Annual point source data (except for CEM data)

Overview of Emissions Processing (cont.)

- Processor contains default factors & profiles, including:
  - County-to-Grid Allocation Factors
  - Temporal Allocation Profiles (hourly & seasonal)
  - Speciation Profiles

Speciation of EC & POA

- Speciation Profiles ~ estimate of the EC & POA portion of each PM2.5 source's emissions
  - All PM2.5 sources "assigned" to 1 of 73 "profiles"
- EC, POA
  - Derived within the Emissions Processor from PM2.5 using speciation profiles
  - NOT part of the NEI
- Current Issues
  - EC – POA Split, carbon analysis methods
  - OC – POA compound adjustment

Process-based Emissions Models

- Space- & time- sensitive emissions reflective of real time conditions
  - wind, temperature
  - RH, vegetation types
  - soil type & moisture
- Linkage:
  - MM5
  - GIS coverages
  - Emission algorithms
- Currently ~ BEIS3, MOBILE6
  - No other categories linked to real time conditions

Process-based Emissions Models (cont.)

- Process-based emission model needs
  - Ammonia (fertilizer application, animal husbandry, removal)
  - Fugitive Dust (wind, unpaved roads, construction, tilling, removal)
  - Wildland Fires (fuels, fuel consumption, plume rise)
  - Residential Wood Burning
  - Evaporative Loss
  - Others ?

Status of Process-based Emissions Models (Integrated w/ Emissions Processor)

- Biogenics (always integrated w/ EP)
- On-Road (optional integration w/ EP)
- Ammonia (development just began)
- Fugitive Dust (under development)
- Wildland Fire (under development)

Wildland Fire Emissions Module (under development)

- Modular input to Emission Models (e.g., SMOKE, OpEM) to interface with the CMAQ modeling system.
- User Inputs: Fire locations, duration, size

Wildland Fire Emissions Module (under development) (cont.)

- Model Components
  - Fuel loading default: NFDRS / FCC map
  - Fuel Moisture: Calculates using MM5 met data
  - Fuel Consumption: CONSUME2.1 / FOFEM
  - Emissions, Heat Release & Plume Rise: EPM & Briggs (modified)

Wildland Fire Emissions Module (under development) (cont.)

- Outputs: Gridded hourly emissions, plume characteristics
- Integrate, Test & Release Module (late 2004 earliest – w/ funding)

Fugitive Dust Emissions Module (under development)

- Modular input to Emission Models (e.g., SMOKE, OpEM) to interface with the CMAQ modeling system. It will:
  - establish consistent database of resource info (soil map, land use, vegetation cover, moisture, precipitation, wind speed) for making emission estimates for use with grid models.
  - demonstrate proof-of-concept of emission models for wind erosion, unpaved roads, construction, other dust sources.

Receptor Models

- Inventory refinement, bounding uncertainties
  - Fossil vs Contemporary Carbon
  - Gas vs diesel
  - Cold starts, smokers

Specific PM2.5 Categories Needing Input from Federal / State / Local / Tribes

- Wildland Burning
  - Forests, Rangeland & especially private & State / tribal burners
  - (acreages burned, fuel loadings for largest fires, timing)
- Residential Open Burning
  - Household Waste, Yard waste (volumes & burning practices)
  - Regulations & their effectiveness, local surveys of burn activities)

Specific PM2.5 Categories Needing Input from Federal / State / Local / Tribes (cont.)

- Construction Debris & Logging Slash
  - Regulations & their effectiveness, local surveys of burn activities
- Agricultural Field Burning
  - Acreages, fuel loadings, timing
- Residential Wood Combustion
  - Fireplaces, Wood Stoves
  - local surveys of fuel burned, fireplace vs wood stoves, local regulations

Specific PM2.5 Categories Needing Input from Federal / State / Local / Tribes (cont.)

- Area-specific industrial process sources
- Fugitive Dust as indicated by local conditions

Preparation of Fine Particulate Emissions Inventories

Chapter 3 – Onroad Mobile Sources

MOBILE 6 Overview

- Use MOBILE 6 model for emission factors
  - $PM_{2.5}$, SO_2, NO_x, NH_3, PM_{10}, VOC, and CO
  - $PM_{2.5}$ and PM_{10} emission factors are for primary emissions (PM2.5-PRI and PM10-PRI)
- Use vehicle miles traveled (VMT) data for activity
- Map VMT data to corresponding MOBILE 6 emission factors

MOBILE 6 Overview (cont.)

- Data and algorithms previously in PART5 (with updates where applicable) have been integrated into the MOBILE 6 model
- Fugitive dust emission factors included in PART5 (i.e., re-entrained road dust) removed from MOBILE 6
- MOBILE 6 also includes emission estimates for Gaseous SO_2 and Ammonia (NH_3)

MOBILE 6 Modeling Inputs

- Use same inputs for MOBILE 6 model as used for previous MOBILE 6 model for same time period
  - Registration distribution
  - Ambient conditions
  - Speeds/speed distribution
  - Fuel parameters
  - Control programs
  - VMT mix

MOBILE 6 Modeling Inputs (cont.)

- Additional data required for MOBILE 6
  - Diesel sulfur content (in parts per million [ppm])
- Additional commands needed for MOBILE 6
  - Described in MOBILE User's Guide
- $PM_{2.5}$ and PM_{10} emission factors cannot be calculated in same scenario—particle size must be specified in each scenario

National Mobile Inventory Model (NMIM)

- Creates national or sub-national emission inventories
- Consolidated emissions modeling system
- Combines a graphical user interface, MOBILE, NONROAD, and a data base
- Data base contains most recent information used in the NEI

National Mobile Inventory Model (NMIM) (cont.)

- Calculates criteria pollutants and HAP emissions
- All estimates based on same input parameters
- Used to generate preliminary 2002 NEI for nonroad engines
- Optional for states
- Available for general use in 2004
- Produces same results as MOBILE and NONROAD

Sources of VMT Data

- State Department of Transportation
- Metropolitan Planning Organization
- 1999 NEI VMT Data based on:
  - State-provided VMT (8 States)
  - FHWA HPMS data summaries
    - By roadway type and State
    - By roadway type and Urban Area
    - Nationally by Vehicle Type

VMT Approach

- Distributions of VMT by roadway type, vehicle type, by hour of day can be applied directly to VMT or included within MOBILE 6 input files
- Also need to have speeds matched to roadway types either as average speeds or as speed distributions by speed ranges

Level of Detail of VMT Data

- By county
- By roadway type (or link level)
- By vehicle type
- Appropriate time period

Calculating Onroad Emissions

- Match VMT to corresponding MOBILE 6 emission factor
  - Map according to speed, roadway type (RT), vehicle TYPE (VT), time period
- Emis= VMT * EF * K
  - Emis = emissions in tons by RT, VT
  - VMT = vehicle miles traveled on RT by VT in miles
  - EF = emission factor in grams/mile by RT, VT
  - K = conversion factor

Additional Resources

- User's Guide to MOBILE6.1 and MOBILE6.2: Mobile Source Emission Factor Model, EPA420-R-02-028, October 2002
  http://www.epa.gov/otaq/m6.htm
- MOBILE6.1 Particulate Emission Factor Model Technical Description, Draft, EPA420-R-02-012, March 2002
  http://www.epa.gov/OMS/models/mobile6/r02012.pdf
- Links to MOBILE6 Training Materials
  http://www.epa.gov/otaq/m6.htm#m6train

Preparation of Fine Particulate Emissions Inventories

Chapter 4 – Nonroad Mobile Sources

What Sources are Included?

SCCs (4-digit SCC denotes engine type)

2260xxxxxx	2-Stroke Gasoline
2265xxxxxx	4-Stroke Gasoline
2267xxxxxx	Liquefied Petroleum Gasoline (LPG)
2268xxxxxx	Compressed Natural Gas (CNG)
2270xxxxxx	Diesel

Two exceptions:

2282xxxxxx	Recreational Marine
2285xxxxxx	Railroad Maintenance

What Sources are Included? (cont.)

Equipment Category (7-digit SCC denotes equipment)

- Airport ground support
- Agricultural
- Construction
- Industrial
- Commercial
- Residential/commercial Lawn and garden
- Logging
- Recreational marine vessels
- Recreational equipment
- Oil field
- Underground mining
- Railway maintenance

10-digit SCC generally denotes specific application within equipment category

What Sources are Included? (cont.)

- Pollutants
  - PM10-PRI, PM2.5-PRI, CO, NO_x, VOC, SO_2, and CO_2
    - PM_{10} and $PM_{2.5}$ emission factors represent Primary PM
    - NH_3 not a direct output of NONROAD, can be estimated based on fuel consumption and EPA emission factors derived from light-duty onroad vehicle emission measurements
    - Model estimates exhaust and evaporative VOC components

4-4 Preparation of Fine Particulate Emissions Inventories

NONROAD Model Emission Equation

$$I_{exh} = E_{exh} * A * L * P * N$$

where:

I_{exh}	=	Exhaust emissions, (ton/year)
E_{exh}	=	Exhaust emission factor, (ton/hp-hr)
A	=	Equipment activity, (hours/year)
L	=	Load factor, (proportion of rated power used on average basis)
P	=	Average rated power for modeled engines, (hp)
N	=	Equipment population

4-5 Preparation of Fine Particulate Emissions Inventories

NONROAD Model Emission Equation (cont.)

- Emission Factors
  - Dependent on engine type and engine size (horsepower)
    - Future year emission controls or standards reflected in emission factor value
  - SO_2, CO_2, and evaporative VOC emissions based on fuel consumption
  - PM_{10} assumed to be equivalent to total PM
    - For gasoline and diesel-fueled engines, $PM_{2.5} = 0.92 * PM_{10}$
    - For LPG and CNG-fueled engines, $PM_{2.5} = PM_{10}$

4-6 Preparation of Fine Particulate Emissions Inventories

Geographic Allocation

- County-level allocation of equipment population
  - National or state-level equipment populations from PSR or alternate sources, reported by equipment type (SCC) and horsepower range
  - Allocates populations to counties using surrogate indicators that correlate with nonroad activity for specific equipment types

Temporal Allocation

- NONROAD accounts for temporal variations in activity
  - Monthly activity profiles by equipment category according to 10 geographic regions
  - Typical weekday and weekend day activity profiles by equipment category; do not vary by region

Improving Inputs

- Specify local fuel characteristics and ambient temperatures
- Replace NONROAD model default activity inputs with State or local inputs
  - Perform local survey
- Obtain local information to improve geographic allocation indicators and temporal profiles

Improving Inputs (cont.)

- Significant PM Fine Equipment Categories include:
  - Diesel construction
  - Diesel farm
  - Diesel industrial
  - Gasoline lawn and garden
  - Gasoline recreational marine

Resources

http://www.epa.gov/otaq/nonrdmdl.htm

- From this web site, there are links to:
  - Downloadable version of NONROAD2002a model
  - Documentation
    - User's Guide
    - Technical Reports to describe the sources and development of all model default input values

AIRCRAFT - Overview

- SCCs
  - 2275020000 – Commercial Aircraft
  - 2275050000 – General Aviation
  - 2275060000 – Air Taxis
  - 2275001000 – Military Aircraft
- Activity Data – landing and take-off operations (LTOs)
- Emission Factors – aircraft/engine-specific or fleet average

AIRCRAFT - Overview (cont.)

- Definitions of Aircraft Categories:
  - Commercial - Aircraft used for scheduled service to transport passengers, freight, or both
  - Air taxis - Smaller aircraft operating on a more limited basis to transport passengers and freight
  - General aviation - aircraft used on an unscheduled basis for recreational flying, personal transportation, and other activities, including business travel
  - Military aircraft - aircraft used to support military operations

AIRCRAFT - Overview (cont.)

- Aircraft operations are defined by landing and take-off operation (LTO) cycles, consisting of five specific modes:
  - Approach
  - Taxi/idle-in
  - Taxi/idle-out
  - Take-off
  - Climb-out
- The operation time in each of these modes (TIM) is dependent on the aircraft category, local meteorological conditions, and airport operational considerations

COMMERCIAL AIRCRAFT NEI Method

- Activity/Emissions Developed at National Level
  - Commercial Aircraft Emissions
    - Calculated using national-level FAA LTO data by aircraft type and emission rates from Emissions and Dispersion Modeling System (EDMS) Version 4.0.
    - Used default engines for each aircraft type and default time-in-mode values.

General Aviation, Air Taxi and Military Aircraft – NEI Method

- National Emissions for General Aviation, Air Taxi, and Military Aircraft calculated using equation:

$$National\ Emissions_{c,p} = National\ LTOs_c * EF_{c,p}$$

where:
- $LTOs$ = landing and take-off operations;
- EF = emission factor;
- c = aircraft category; and
- p = criteria pollutant.

General Aviation, Air Taxi and Military Aircraft – NEI Method (cont.)

- LTO-based PM Emission Factors
  - General Aviation
    - PM10-PRI: 0.2367 lbs/LTO
  - Air Taxi and Military Aircraft
    - PM10-PRI: 0.60333 lbs/LTO
  - PM2.5-PRI Emissions
    - Estimated by applying particle size multiplier developed for related engines to PM_{10} emissions estimate
    - PM2.5-PRI = 0.92 * PM10-PRI

AIRCRAFT - NEI Method

- National Emissions Allocation for Each Aircraft Category

$$Airport\ Emissions_{c,p,x} = National\ Emissions_{c,p} * AF_{c,p,x}$$

where:
- AF = allocation factor; and
- x = airport (e.g. La Guardia)
- c = aircraft category; and
- p = criteria pollutant.

$$AF_{c,x} = LTOs_{c,x}/National\ LTOs_c$$

AIRCRAFT - NEI Method (cont.)

- Documentation on the procedures used to develop criteria pollutant (as well as HAP) aircraft emission estimates is available at:

ftp://ftp.epa.gov/EmisInventory/finalnei99ver3/criteria/documentation/nonroad/99nonroad_voli_oct2003.pdf

AIRCRAFT - General Approach

- Determine the mixing height to be used to define the LTO cycle
- Define the fleet make-up for each airport
- Determine airport activity in terms of the number of LTOs by aircraft/engine type
- Select emission factors for each engine model associated with the aircraft fleet

AIRCRAFT - General Approach (cont.)

- Estimate the time-in-mode (TIM) for the aircraft fleet at each airport
- Calculate emissions based on aircraft LTOs, emission factors for each aircraft engine model, and estimated aircraft TIM
- Aggregate the emissions across aircraft

COMMERCIAL AIRCRAFT Improvements to NEI

- Determine engine types associated with local aircraft types, to replace default aircraft/engine assignments in EDMS
- Obtain information on climb-out, takeoff, approach times, as well as taxi/idle times

COMMERCIAL AIRCRAFT Improvements to NEI (cont.)

- For PM_{10} and $PM_{2.5}$, match few emission factors from EPA's 1992 Volume IV, Mobile Sources Procedures document, to the aircraft engines in their fleet as best as possible
- EPA OTAQ working with FAA to develop updated aircraft PM emission factors
- Regional inventories have used PM-10/NO_x emission factor ratios for air taxi applied to commercial aircraft NO_x emissions

GA, AT and Military Aircraft Improvements to NEI

- Obtain local estimates of LTOs for these categories (to obtain LTOs not covered by FAA data)
- Obtain information on the aircraft/engine types that comprise the aircraft fleet for these categories. Apply EPA engine-specific emission factors or EDMS, if available

COMMERCIAL MARINE VESSELS Overview

- Commercial Marine Vessel SCCs
  - 2280002100 – Diesel, In Port
  - 2280002200 – Diesel, Underway
  - 2280003100 – Residual, In Port
  - 2280003200 – Residual, Underway

COMMERCIAL MARINE VESSELS NEI Method

- National Diesel and Residual Emissions split into port and underway components
- Port and underway activity allocated separately, assigned to counties
- Port emissions assigned to a single county in port area

COMMERCIAL MARINE VESSELS NEI Method (cont.)

- Documentation on the procedures used to develop criteria pollutant (as well as HAP) commercial marine emission estimates is available at:

ftp://ftp.epa.gov/EmisInventory/finalnei99ver3/criteria/documentation/nonroad/99nonroadvoli_oct2003.pdf

COMMERCIAL MARINE VESSELS Improvements to NEI

- Review 1999 NEI emission estimates for representativeness
- Allocate port emissions to ports other than 150 largest
- Allocate port emissions to appropriate counties, since port emissions assigned to a single county in port area

COMMERCIAL MARINE VESSELS Improvements to NEI (cont.)

- Obtain activity estimates at the local or State-level from Department of Transportation, Port Authority
  - Fuel consumption
  - Categories of vessels
  - Number and size (hp) of vessels in each category
  - Number of hours at each time-in-mode
    - Cruising
    - Reduced speed zone
    - Maneuvering
    - Hotelling

COMMERCIAL MARINE VESSELS Emission Calculation

Emissions = Pop * HP * LF * ACT * EF

where:

Pop	= Vessel Population or Ship Calls
HP	= Average Power (hp)
LF	= Load Factor (fraction of available power)
ACT	= Activity (hrs)
EF	= Emission Factor (g/hp-hr)

COMMERCIAL MARINE VESSELS Activity

- 1999 EPA studies:
  - *Commercial Marine Activity for Deep Sea Ports in the United States*
  - *Commercial Marine Activity for Great Lake and Inland River Ports in the United States*
- Studies provide activity profiles for select ports, and present method for an inventory preparer to allocate detailed time-in-mode activity data from a typical port to another similar port

COMMERCIAL MARINE VESSELS Activity (cont.)

- Activity profiles for typical port include:
  - Number of vessels in each category
  - Vessel Characterization, including propulsion size (horsepower), capacity tonnage, and engine age
  - Number of hours at each time-in-mode associated with cruising, reduced speed zone, maneuvering, and hotelling

COMMERCIAL MARINE VESSELS Activity (cont.)

- Data on the number of trips and the tons of cargo handled by vessel type are provided for the top 95 Deep Sea Ports and top 60 Great Lake and Inland River Ports
- More detailed activity for these ports can then be estimated based on the data calculated for a typical port

COMMERCIAL MARINE VESSELS Emission Factors

- Depending on activity data obtained:
  - Horsepower-based emission factors
  - Fuel-based emission factors
- EPA performing studies to develop updated emission rates
  - Category 3 Engine Final Rulemaking, January 2003

COMMERCIAL MARINE VESSELS Emission Factors (cont.)

- PM10-PRI EFs for Category 1 and Category 2 Engines:

Engine Category	PM10 [g/kW-hr]
Category 1: 37-75 kW	0.90
Category 1: 75-225 kW	0.40
Category 1: 225+ kW	0.30
Category 2 (5-30 l/cylinder)	0.32

COMMERCIAL MARINE VESSELS Emission Factors (cont.)

- PM10-PRI EFs for Category 3 Engines (> 30 l/cylinder):

Mode: Engine	PM10 [g/kW-hr]
Cruise and Reduced Speed Zone: 2-stroke	1.73
Cruise and Reduced Speed Zone: 4-stroke	1.76
Maneuvering: 2-stroke	2.91
Maneuvering: 4-stroke	2.98
Hotelling: 2-stroke	0.32
Hotelling: 4-stroke	0.32
All Modes: Steam Generators	2.49

COMMERCIAL MARINE VESSELS Emission Factors (cont.)

- Emission factors in grams per gallon fuel consumed also available from *Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources*, EPA-450/4-81-026d (Revised), U.S. EPA, OAQPS, July 1989
- PM2.5-PRI = 0.92 * PM10-PRI emissions

LOCOMOTIVES Overview

SCCs:

- 2285002006 – Diesel Class I Line Haul
- 2285002007 – Diesel Class II/III Line Haul
- 2285002008 – Diesel Passenger (Amtrak)
- 2285002009 – Diesel Commuter
- 2285002010 – Diesel Switchyard Locomotives

LOCOMOTIVES NEI Methods

- PM Emission Factors (represent Primary PM)
  - Line-Haul
    - PM_{10}: 6.7 g/gallon
    - $PM_{2.5}$: 6.03 g/gallon
  - Yard
    - PM_{10}: 9.2 g/gallon
    - $PM_{2.5}$: 8.28 g/gallon

LOCOMOTIVES
NEI Methods (cont.)

- Activity Data (Gallons of distillate fuel oil consumed)
- National Activity
  - 1999 year U.S. distillate consumption by railroads
    - Class I
    - Class II/III
    - Passenger
    - Commuter
- Class I Line-Haul versus Yard (Switch) Operation Activity
  - Multiplied National Class I consumption by estimated line-haul percentage of total fuel consumption

LOCOMOTIVES
NEI Methods (cont.)

- County-level emissions allocation
  - National emissions allocated to counties based on ratio of county to national rail activity
  - Rail activity measured as product of density (gross ton miles per mile) on each rail line and mileage for the associated rail line in county determined through GIS analysis

LOCOMOTIVES
NEI Methods (cont.)

- Detailed documentation on the procedures used to develop criteria pollutant locomotive emission estimates for the 1999 NEI are available at:

ftp://ftp.epa.gov/EmisInventory/finalnei99ver3/criteria/documentation/nonroad/99nonroad_voli_oct2003.pdf

LOCOMOTIVES
Improving the NEI

- Review NEI emission estimates for representativeness
- Obtain more representative fuel consumption estimates at the local or State-level
- Determine relative contribution of line-haul versus yard activity at local or State-level

LOCOMOTIVES
Case Study - Overview

- Case Study: County-level Locomotive Inventory for Sedgwick County, KS
  - See Case Study Number 4-1

LOCOMOTIVES
Case Study – Solution

- Case Study: County-level Locomotive Inventory for Sedgwick County, KS
  - See Handout 4-1

Preparation of Fine Particulate Emissions Inventories

Chapter 5 – Point Source Inventory Development

How Do I Define a Point Source of PM Fine or NH_3 Emissions?

- Point sources are stationary sources included in a point source inventory
- Total plant (facility) emissions for a given pollutant is usually the criterion for deciding what sources to include in a point source inventory
- Criteria for including a stationary source in a point source inventory are determined by:
  - State, Local, or Tribal regulations or policy, and/or
  - Consolidated Emissions Reporting Rule (CERR)

Filterable vs. Condensable

- Filterable PM are directly emitted
  - Solid or liquid
  - Captured on filter
  - PM_{10} or $PM_{2.5}$
- Condensable PM is in vapor phase at stack conditions
  - Reacts upon cooling and dilution
  - Forms solid or liquid particle
  - Always $PM_{2.5}$ or less

Sources of Filterable versus Condensible Emissions

- Combustion sources typically emit both filterable and condensible PM emissions
  - Boilers
  - Furnaces/kilns
  - Internal combustion engines (reciprocating & turbines)
- Fugitive dust sources emit filterable emissions only
  - Storage piles
  - Unpaved roads at industrial sites

Primary vs. Secondary PM

- Primary PM is directly emitted and the sum of filterable and condensable
- Secondary PM is formed through chemical reactions and formed downwind of the source
  - Precursors include SO_2, NOx, and VOC
  - Should not be reported in the inventory

Sources of NH_3 Emissions

- Industrial NH_3 emissions can be placed into 3 broad categories related to the nature of the emissions source:
  - Emissions from industrial processes
  - Use of NH_3 as a reagent in NO_x control
  - Refrigeration losses

Sources of NH_3 Emissions (cont.)

- Examples of industrial processes that emit NH_3 include:
  - Combustion sources
  - Ammonium nitrate & ammonium phosphate production
  - Petroleum refining
  - Pulp and paper production
  - Beet Sugar Production
- These industrial processes represent the more significant emitters of NH_3 in 2000 Toxics Release Inventory (TRI)

Resources for Identifying Point Sources of PM Fine and NH_3

- EIIP Point Source Guidance (Volume II)
  - List documents applicable to PM fine categories
- AP-42
- Existing Inventories
  - National Emissions Inventory
  - Toxics Release Inventory (TRI) for NH_3

What to Report to EPA

- PM2.5-PRI (or PM2.5- FIL & PM-CON individually)
  - Note that all PM-CON is assumed to be $PM_{2.5}$ size fraction
- PM10-PRI (or PM10-FIL & PM-CON individually)

Implications

- Use the NIF 3.0 PM pollutant code extensions that identify the forms of PM (i.e., –PRI, –FIL, or –CON)
- Verify the form of the PM:
  - Emission factors you use to calculate emissions; and
  - PM emissions facilities report to you.
- Update your database management system to record these pollutant codes in NIF 3.0

How Do I Identify the PM Form?

- Test Methods upon which emission factors or emissions are based determine the form of PM:
  - PM-FIL:
    - EPA Reference Method 5 series, Method 17, Method 201/201A
  - PM10-FIL/PM2.5-FIL:
    - Particles-size analysis of PM-FIL (e.g., AP-42 EFs)
    - Preliminary Method 4 being developed by EPA to measure both
  - PM-CON:
    - EPA Reference Method 202

AP-42 Particle Size Data

- Provides particle size distribution data and particle-size-specific emission factors
  - Use AP-42 if source-specific data are not available
    - Use data in chapters for specific source categories first
    - Use Appendix B-1 data next
    - Use Appendix B-2 data last

AP-42 Particle Size Data (cont.)

- AP-42 chapters not always clear on what source test methods were used to develop particle size data
  - See background documents for AP-42 chapters for details
- AP-42 available on EPA/OQAPS CHIEF web site
  - http://www.epa.gov/ttn/chief/

AP-42 Particle Size Data (cont.)

- Appendix B-1 (Particle Size Distribution Data and Sized Emission Factors for Selected Sources)
  - Based on documented emission data available for specific processes
- Appendix B-2 (Generalized Particle Size Distributions)
  - Based on data for similar processes generating emissions from similar materials
  - Generic distributions are approximations
  - Use only in absence of source-specific distributions

Factor Information Retrieval (FIRE) Data System

- Latest version available was last updated October 2000 (Version 6.23)
- Currently being updated to:
  - Incorporate revisions to 10 AP-42 chapters
  - Add more PM10-FIL, PM25-FIL, and PM-CON emission factors

PM Calculator

- EPA tool for calculating uncontrolled/controlled filterable $PM_{2.5}$ and PM_{10} emissions using AP-42 particle size distributions
- For point sources only
- Contains 2,359 SCCs with PM_{10} emissions in 1996 NEI

PM Calculator (cont.)

- Limitations
  - AP-42 particle size data not available for many sources; generic AP-42 profiles are used for many source categories
- Available on EPA/OQAPS CHIEF web site
  - http://www.epa.gov/ttn/chief/software/index.html

Point & Area Source Emissions Inventory (EI) Overlap Issues

- For categories included in Point and Area EIs:
  - Subtract total point activity from total state activity to obtain total area activity

$$\text{Total Area Activity} = \text{Total Activity} - \Sigma \text{ Total Point Activity}$$

- Example for Fuel Combustion Sources:
  - Point activity: fuel throughput from point source EI survey
  - Total activity: fuel throughput from State/local gov. agencies or U.S. DOE/EIA State Energy Data reports

Point & Area Source EI Overlap Issues (cont.)

- Basis of Point Source Subtraction
  - Activity-based calculation is preferred
  - Emissions-based calculation is acceptable when activity is not available:
    - Total source category activity and point activity need to be on same control level (usually uncontrolled)
    - Back-calculation of uncontrolled emissions for controlled processes may overstate uncontrolled emissions

Point & Area Source EI Overlap Issues (cont.)

- Geographic level of calculation may affect results:
  - Issue when using surrogate activity data (e.g., employment, housing, population) to allocate total State activity to counties
  - Subtracting county totals may produce negative results due to inaccuracy of allocation method
  - Subtracting State totals less likely to produce negative results at county level
  - Point source adjustments to surrogate allocation data (e.g., employment) should be done if available from point EI survey

Point & Area Source EI Overlap Issues (cont.)

- QA/QC Results
  - Review county-level area source estimates for reasonableness
  - Make adjustments based on experience of your agency's personnel:
    - If allocation method places area source activity in a county for which you know there is no activity, exclude the county from your allocation
    - If all of a county's activity is covered by the point EI, set the activity for the county to zero

Point & Area Source EI Overlap Issues (cont.)

- Reporting of small point sources in area CERR submittal:
  - If your point EI includes sources with emissions below the CERR point EI reporting thresholds, you may include the emissions for these small sources in the area EI
  - To avoid double counting in the area EI, subtract total point source activity or emissions from total State-level activity or emissions before rolling up emissions for small point sources to be included in your area EI

Reading List

- *Stationary Source Control Techniques Document for Fine Particulate Matter*, EPA/OAQPS, Oct. 1998
  (http://www.epa.gov/ttn/oarpg/t1/meta/m32050.html)
- *Emission Inventory Guidance for Implementation of Ozone and Particulate Matter National Ambient Air Quality Standards (NAAQS) AND Regional Haze Regulations, EPA/OAQPS*
  (http://www.epa.gov/ttn/chief/eidocs/publications.html)
- *Introduction to Stationary Point Source Emission Inventory Development*, EIIP Vol. 2, Chapter I, May 2001
- *How to Incorporate Effects of Air Pollution Control Device Efficiencies and Malfunctions into Emission Inventory Estimates*, EIIP Vol. 2, Chapter 12, July 2000

Preparation of Fine Particulate Emissions Inventories

Chapter 6 – Nonpoint Sources

How Do I Identify and Estimate Nonpoint Sources of PM Fine or NH_3 Emissions?

- The nonpoint source inventory includes any stationary source that is not included in the point source inventory

How Do I Identify and Estimate Nonpoint Sources of PM Fine or NH_3 Emissions? (cont.)

- EIIP Area Source Guidance (Volume III)
  - Lists PM fine categories for which EIIP guidance is available
- AP-42
- Existing inventories
  - National Emission Inventory (NEI)
  - Toxics Release Inventory (TRI)

How Do I Identify and Estimate Nonpoint Sources of PM Fine or NH_3 Emissions? (cont.)

- EIIP Area Source Guidance (Volume III) for Sources of PM Emissions
  - Chapter 2: Residential Wood Combustion, Revised Final, Jan. 2001
  - Chapter 16: Open Burning, Revised Final, Jan. 2001
  - Chapter 18: Structure Fires, Revised Final, Jan. 2001
  - Chapter 24: Conducting Surveys for Area Source Categories, Dec. 2000

How Do I Identify and Estimate Nonpoint Sources of PM Fine or NH_3 Emissions? (cont.)

- Area Source Category Method Abstracts for Sources of PM Emissions
  - Charbroiling, Dec. 2000
  - Vehicle Fires, May 2000
  - Residential and Commercial/Institutional Coal Combustion, April 1999
  - Fuel Oil and Kerosene Combustion, April 1999
  - Natural Gas and Liquefied Petroleum Gas (LPG) Combustion, July 1999

PM 1-Pagers: Nonpoint Sources

- PM 1-Pagers: Overview
  - Location: PM Resource Center
    - Web site: http://www.epa.gov/ttn/chief/eiip/pm25inventory/areasource.html
  - Purpose:
    - Summarize nonpoint source NEI methods for specific categories of PM_{10}, $PM_{2.5}$, and NH_3

PM 1-Pagers: Nonpoint Sources (cont.)

- Contents:
  - Source Category Name, SCC
  - Pollutants of Most Concern
  - Current NEI Methodology
  - How can States, Locals, and Tribes improve upon methodology?
  - Uncertainties/Shortcomings of Current Methods
  - Activity Variables Used to Calculate Emissions:
  - Current Variables/Assumptions Used
  - Suggestions for Improved Variables
  - Where can I find Additional Information and Guidance?
  - References

PM 1-Pagers: Nonpoint Sources (cont.)

- Open Burning
  - Residential Yard Waste (Leaves) and Household Waste
  - Residential, Nonresidential, and Road Construction Land Clearing Waste
  - Structure Fires
  - Wildfires & Prescribed Burning
  - Managed Burning - Slash

PM 1-Pagers: Nonpoint Sources (cont.)

- Fugitive Dust
  - Paved and Unpaved Roads
  - Residential Construction
  - Mining and Quarrying
- Residential Combustion - Fireplaces and Woodstoves

Typical Source Categories of Filterable PM Emissions

- Fugitive Dust Sources (Crustal PM Fine)
  - Construction
  - Mining and quarrying
  - Paved/unpaved roads
  - Agricultural tilling
  - Beef cattle feedlots

Typical Categories of Filterable and Condensible PM Emissions

- Open Burning Sources (Carbonaceous PM Fine)
  - Open burning
    - Residential municipal solid waste burning
    - Yard waste burning
    - Land clearing debris burning
  - Structure fires
  - Prescribed fires
  - Wildfires
  - Agricultural field burning

Typical Categories of Filterable and Condensable PM Emissions (cont.)

- External/Internal Fuel Combustion (Carbonaceous PM Fine):
  - Residential wood combustion
  - Other residential fuel combustion
  - Industrial fuel combustion
  - Commercial/institutional fuel combustion

Typical Source Categories of NH_3 Emissions

- Typical source categories of NH_3 emissions include:
  - Animal husbandry
  - Agricultural fertilizer application
  - Agricultural fertilizer manufacturing
  - Wastewater treatment

How Do I Estimate Emissions?

- Emissions data prepared and reported by Source Classification Code (SCC)
  - 10-digit SCC defines an nonpoint emission source
  - EPA SCCs located at: http://www.epa.gov/ttn/chief/codes/index.html#scc
- Report actual emissions; not allowable or potential emissions

How Do I Estimate Emissions? (cont.)

- Calculate emissions using:
  - Activity data
  - Emission factors
  - Control efficiency data
  - Rule effectiveness/rule penetration
- Follow EIIP methods when available
  - Provides preferred and alternative methods for collecting activity data and use of emission factors
  - Improve on existing inventory methods

How Do I Estimate Emissions? (cont.)

- Emission estimation equation:

$$CAE_A = (EF_A)(Q)\ [(1- (CE)(RP)(RE)]$$

CAE_A = Controlled nonpoint source emissions of pollutant A
EF_A = Uncontrolled emission factor for pollutant A
Q = Category activity
CE = % Control efficiency/100
RE = % Rule effectiveness/100
RP = % Rule penetration/100

How Do I Estimate Emissions? (cont.)

- Obtain activity data from:
  - Published sources of data
    - National, regional, or state-level activity data often require allocation to counties using county-level surrogate indicator data
  - Survey performed to obtain local estimate of activity

How Do I Estimate Emissions? (cont.)

- Sources of PM and NH_3 emission factors
  - Factor Information Retrieval (FIRE) System
    http://www.epa.gov/ttn/chief/software/fire/index.html
  - AP-42
    http://www.epa.gov/ttn/chief/ap42/index.html
  - Emission factor ratios
    - $PM_{2.5}$ emissions calculated from PM_{10} emissions using ratio of $PM_{2.5}$-to-PM_{10} emission factors
  - State or local emission factors are preferred

How Do I Estimate Emissions? (cont.)

- Control efficiency (CE)
  - Percentage value representing the amount of a source category's emissions that are controlled by a control device, process change, reformulation, or management practice
  - Typically represented as the weighted average control for an nonpoint source category

How Do I Estimate Emissions? (cont.)

- Rule effectiveness (RE)
  - Adjustment to CE to account for failures and uncertainties that affect the actual performance of the control
- Rule penetration (RP)
  - Percentage of the nonpoint source category that is covered by the applicable regulation or is expected to be complying with the regulation

Spatial and Temporal Allocation

- Available national, regional, or state-level activity data often require allocation to counties or subcounties using surrogate indicators
- S/L/T agencies should review estimates developed in this manner (e.g., NEI) for representativeness
- Available temporal profiles to estimate seasonal, monthly, or daily emissions for specific categories may be limited
- States are encouraged to reflect local patterns of activity in their emission inventories

EI Development Approaches

- Approaches Available to State, Local, and Tribal (S/L/T) Agencies:
  - S/L/T Agency develops its own inventory following EIIP procedures
  - Compare S/L/T activity data and assumptions to NEI Defaults – Use S/L/T data to replace NEI defaults if data will improve estimates
  - Use NEI default estimates

Triage Approach to Improving the EI

- Consider each NEI Category - Is it important ?
  - What's its potential impact on AQ, considering emissions, receptor modeling & other available info
  - May give *some weight* to emission reductions potential
- If yes, focus improvement efforts on the important categories
- Review the available guidance (Course materials, one pagers, EIIP guidance)
- Decide what is feasible in the near and long term

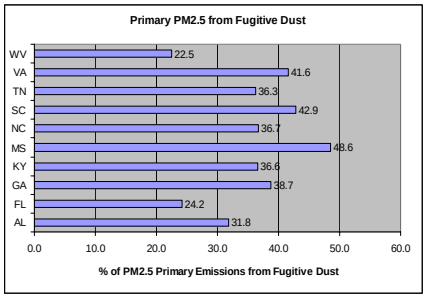
Crustal Materials (Mainly Fugitive Dust)

- Main Sources:
  - Unpaved roads
  - Agricultural tilling
  - Construction
  - Windblown dust, Fly ash

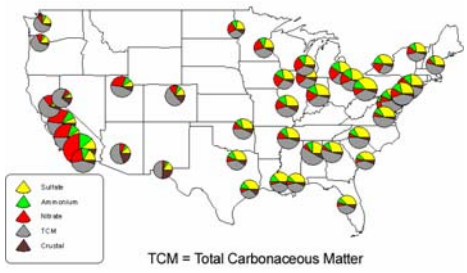
Crustal Materials (Mainly Fugitive Dust) (cont.)

- Huge Disparity Between EI & Ambient Data
  - Ambient Data
    - < 1 ug/m3 in most of US
    - Exception: > 1 ug/m3 in much of Southwest, California
  - Emissions: 2.5M TPY (comparable to Carbon Emissions)
- Fugitive Dust has low "Transportable Fraction"

Fugitive Dust Emissions in VISTAS States



Urban (EPA STN) Annual Averages Sep 2001-Aug 2002



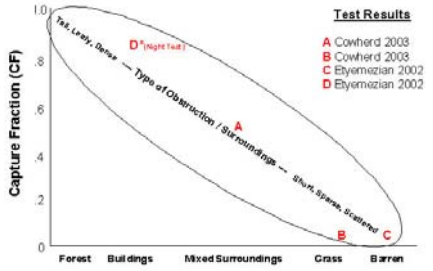
Role of Surface Cover (Vegetation & Structures) in Fugitive Dust Removal

- Early work by AQ Modelers
  - Stilling Zone – Lower 3/4 of canopy
- Windbreaks – wind erosion "staple"
  - Traditionally to slow wind on leeward side
  - Research by Raupach
    - Entrapment effects
    - Dust transmittance through a windbreak is close to the optical transmittance

Role of Surface Cover (Vegetation & Structures) in Fugitive Dust Removal (cont.)

- Capture Fraction (CF)
  - Portion of Fugitive Dust Emissions (FD) removed by nearby surface cover
- Transport Fraction (TF)
  - Portion that is transported from the source area

Capture Fraction ~ Conceptual Model and Field Measurement Results



Estimates of CF for Specific Surface Conditions

Surface Cover Type	CF (Estimated)
Smooth, Barren or Water	0.03 – 0.1
Agricultural	0.1 - 0.2
Grasses	0.2 - 0.3
Scrub and Sparsely Wooded	0.3 - 0.5
Urban	0.6 - 0.7
Forested	0.9 - 1.0

Example CF's for Counties in NV & GA

- CF (County) = ∑ CF (Land Use Types) * County Fractional Land Use
  - Types
    - TF = 1 - CF

Land Use Type	Barren & Water	Agri-culture	Grass	Urban	Scrub & Sparse Vegetation	Forest	CF	TF
CF	.03	.15	.2	.6	.3	.95		
Fractional Land Use in Churchill Co NV	.33	.03	.2	0	.36	.05	0.23	0.77
Fractional Land Use in Oglethorpe Co GA	0	.1	.14	0	0	.76	0.76	0.24

Fugitive Dust Modeling Issues

- Gaussian Models
  - Have many CF removal mechanisms built-in
    - rarely utilized
  - Application requires empirical coefficients ~
    - limited data & guidance
- Grid Models
  - Remix particles w/in lowest layer at each time step (underestimates removal by gravitational settling)
  - Ignore removal processes in initial grid
    - Very significant omission (unless grid is VERY small)

Cautions on Use of the TF in Emissions Inventory & Modeling Applications

- Do NOT use to reduce the emissions inventory
- Do NOT use with Gaussian Models
  - Instead, use features of model properly
- Use with Grid Models (with proper caveats)
  - There ARE other issues with the inventory – the TF concept should NOT be expected to fully account for overestimation of crustal fraction of ambient measurements
- TF concept is evolving
  - Grid Model modifications could (over time) eliminate need for TF concept

Crustal Materials ~ Conclusions

- Crustal materials are a relatively small part of PM2.5 in the ambient air
- Fugitive dust is released near the ground and surface features often capture the dust near its source
- The **Capture / Transport Fraction** concept *does* provide a useful way to account for near source removal when used with Grid Models
  - This area of research offers many opportunities to improve model performance
  - There is much work to do to refine the concept

Preparation of Fine Particulate Emissions Inventories

Chapter 7 – Fugitive Dust Area Sources

AGRICULTURAL TILLING Overview

- SCC
  - 2801000003
- Pollutants
  - Filterable PM_{10}, $PM_{2.5}$

AGRICULTURAL TILLING NEI Method

- Activity Data (no. of acres of land tilled)
  - 1998 County-Level Activity Data
    - Acres of crops tilled in each county by crop type and by tilling method obtained from CTIC
    - Five tilling methods include:
      - no till
      - mulch till
      - ridge till
      - 0 to 15 percent residue
      - 15 to 30 percent residue

AGRICULTURAL TILLING NEI Method (cont.)

- Emission Factor (mass of TSP per acre tilled)
  - Emission factor comprises:
    - Constant of 4.8 lbs/acre pass
    - Silt content of the surface soil
    - Number of tillings per year (conservation and conventional use)
    - Particle size multiplier for PM_{10} and $PM_{2.5}$

AGRICULTURAL TILLING NEI Method (cont.)

- Emission Factor (cont.)
  - Silt content

Soil Type	Silt Content (%)
Silt Loam	52
Sandy Loam	33
Sand	12
Loamy Sand	12
Clay	29
Clay Loam	29
Organic Material	10-82
Loam	40

  - Soil types assigned to counties by comparing USDA surface soil and county maps

AGRICULTURAL TILLING NEI Method (cont.)

- Emission Factor (cont.)
  - Number of Tillings

Crop	Conservation Use	Conventional Use
Corn	2	6
Spring Wheat	1	4
Rice	5	5
Fall-Seeded Small Grain	3	5
Soybeans	1	6
Cotton	5	8
Sorghum	1	6
Forage	3	3
Permanent Pasture	1	1
Other Crops	3	3
Fallow	1	1

AGRICULTURAL TILLING
NEI Method (cont.)

- Emission Calculation

$$E = c * k * s^{0.6} * p * a$$

where: E = PM emissions, lbs per year
c = constant 4.8 lbs/acre-pass
k = dimensionless particle size multiplier (PM_{10}= 0.21; $PM_{2.5}$ = 0.042)
s = silt content of surface soil, defined as the mass fraction of particles smaller than 75 µm diameter found in soil to a depth of 10 cm (%)
p = number of passes or tillings in a year
a = acres of land tilled

AGRICULTURAL TILLING
NEI Method (cont.)

- Emission equation used for years prior to 1999
- For 1999/2002, number of acres tilled for each of the five tillage types was estimated based on linear interpolation of national-level data available for 1998 and 1999/2002
- Developed national growth factors by tillage type for 1999/2002, using 1998 as basis
- Growth factors applied to county level emissions for 1998 to estimate county level emissions for 1999/2002
- Assumed no controls

AGRICULTURAL TILLING
Improving the NEI

- Use crop-specific acreage and tilling practice data from state/local agencies
- Use state/local emission factors
- Perform field study to determine local silt content percentage of surface soil
- Crop Calendars: Develop using state/local data to determine time and frequency of activities (e.g., land prep., planting, and tilling)

California Air Resources Board (CARB) Study

- Reference
  - *Computing Agricultural PM_{10} Fugitive Dust Emissions Using Process Specific Emission Rates and GIS,* Patrick Gaffney and Hong Yu, CARB
  - Presented at 12th International Emission Inventory Conference, San Diego, CA, April 29 May 1, 2003
  - Paper and slides available in PDF files:

http://www.epa.gov/ttn/chief/conference/ei12/index.html

CARB Study (cont.)

- Statewide PM_{10} EI for:
  - Land preparation activities
  - Harvest activities
- Goals:
  - Obtain current, crop-specific acreage data
  - Develop crop-specific temporal profiles (crop calendars)
  - Develop emission factors for all crops

CARB Study (cont.)

- Crop-specific Acreage Data
  - County-level data from CA Dept. of Food and Agriculture
  - Data generated annually by crop and by county
  - Includes over 200 crops and 30 million acres

CARB Study (cont.)

- Crop Calendars
  - Developed for 20 most important crop types
    - Importance based on acreage and potential emissions
  - Define temporal periods of farming operation activities by crop type

Example Crop Calendar for Corn

Farming Operations	Crop Cycles Per Year	Passes Per Crop Cycle	Fraction of Acreage Per Cycle	Passes During Month											
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Land Preparation															
Stubble Disc	1	1	1.0												
Finish Disc	1	1	1.0												
List & Fertilize	1	1	1.0												
Mulch Beds	1	1	1.0												
Planting	1	1	1.0												
Cultivation	1	2	1.0												
Harvesting	1	1	1.0												

(Reference: *Computing Agricultural PM_{10} Fugitive Dust Emissions Using Process Specific Emission Rates and GIS*, prepared by Patrick Gaffney and Hong Yu from California Air Resources Board for U.S. EPA 2003 Annual Emission Inventory Conference.)

CARB Study (cont.)

- Emission Factors (EFs)
  - Previous EIs:
    - Land Preparation: AP-42 Tilling factor (4.0 (lbs PM_{10}/acre-pass) applied to all operations
    - Harvesting: Estimated for only 3 crop types for which EFs were available
  - Improvements:
    - Conducted field testing to develop EFs for more operations
    - Crop & operation specific (for crop calendars)

CARB Study (cont.)

Land Preparation Emission Factors

	(lbs PM_{10}/acre-pass)
Root Cutting	0.3
Discing, Tilling, Chiseling	1.2
Ripping, Subsoiling	4.6
Land Planning & Floating	12.5
Weeding	0.8

- EFs used as surrogates for other land prep. operations

CARB Study (cont.)

Harvest Emission Factors

	(lbs PM_{10}/acre-pass)
Cotton Harvest	3.4
Almond Harvest	40.8
Wheat Harvest	5

- Assigned to over 200 crop types and adjusted using a "division factor" based on consultation with agricultural industry

PAVED ROADS Overview

- SCC: 2294000000
- Pollutants
  - PM_{10}, $PM_{2.5}$

PAVED ROADS
NEI Method

- Activity Data [vehicle miles traveled (VMT) on paved roads]
  - State-Level Activity Data

State/road type level VMT from paved roads =
Total State/road type-level VMT - State/road type-level unpaved road VMT

  - Because of differences in methodology between the calculation of total and unpaved VMT, there may be cases where unpaved VMT is higher than total VMT
  - In these cases, unpaved VMT is reduced to total VMT, and paved road VMT is assigned a value of zero

PAVED ROADS
NEI Method (cont.)

- Activity Data [vehicle miles traveled (VMT) on paved roads] (cont.)
  - Paved road VMT temporally allocated by month using NAPAP temporal allocation factors for total VMT.

PAVED ROADS
NEI Method (cont.)

- Emission Factor
  - Empirical emission factor equation from AP-42

$$PAVED = PSDPVD * (PVSILT/2)^{0.65} * (WEIGHT/3)^{1.5} - C$$

where:

PAVED	=	paved road dust emission factor for all vehicle classes combined (grams per mile)
PSDPVD	=	constant for particles of less than 10 microns in diameter (7.3 g/mi for PM_{10})
PVSILT	=	road surface silt loading (g/m^2)
WEIGHT	=	average weight of all vehicle types combined (tons)
C	=	emission factor for 1980's vehicle fleet exhaust, brake wear, and tire wear

PAVED ROADS
NEI Method (cont.)

- Emission Factor (cont.)
  - Paved road silt loadings assigned to each of the twelve functional roadway classifications
    - Road types with average daily traffic volume (ADTV) < 5,000 vehicles per day = 0.20 g/m^2
    - Freeways = 0.015 g/m^2
  - See AP-42, Section 13.2.1 for more information
  - AP-42 emission factors for paved roads only apply to reentrained dust
  - Use MOBILE model for estimating PM from tailpipe exhaust, brake wear, and tire wear.

PAVED ROADS
NEI Method (cont.)

- Emission Factor (cont.)
  - Adjustments for precipitation

    Emission factor multiplied by a rain correction factor, calculated as follows:

    *(365 - p * 12 * 0.5) / 365*

where: *p* = the number of days in a given month with greater than 0.01 inches of precipitation

  - Precipitation data used in the paved road emission factor calculations were taken from stations representative of urban areas in each state
  - Final emission factors developed by month at the State and road type level for the average vehicle fleet

PAVED ROADS
NEI Method (cont.)

- Emission Calculation

$$EM_{s,r,m} = VMT_{s,r,m} * EF_{s,r,m}$$

where: EM = PM_{10} emissions, tons per month
VMT = VMT, miles per month
EF = tons per mile
M = month
S = State
R = road type class

$PM_{2.5} = PM_{10}$ emissions x 0.25

PAVED ROADS
NEI Method (cont.)

- Allocation of State Emissions to County Level
  - Paved road emissions are allocated to the county level according to the fraction of total State VMT in each county for the specific road type

$$PVDEMIS_{X,Y} = PVDEMIS_{ST,Y} * VMT_{X,Y}/VMT_{ST,Y}$$

where:
- $PVDEMIS_{X,Y}$ = paved road PM emissions (tons) for county x and road type y
- $PVDEMIS_{ST,Y}$ = paved road PM emissions (tons) for the entire State for road type y
- $VMT_{X,Y}$ = total VMT (million miles) in county x and road type y
- $VMT_{ST,Y}$ = total VMT (million miles) in entire State for road type y

PAVED ROADS
NEI Method (cont.)

- Controls
  - Control efficiency of 79 percent applied to:
    - Urban and rural roads in serious PM NAAs; and
    - Urban roads in moderate PM NAAs
      - Corresponds to vacuum sweeping on paved roads twice per month
  - Rule penetration varies by road type and NAA classification (serious or moderate)

PAVED ROADS
Improvements to NEI Method

- VMT on paved roads for local area

  (Source: State Dept. of Transportation, Mobile Source Section of Environmental Dept)

- Local registration data representing the average weight of vehicles (since this variable is weighted most heavily)

  (Source: State Dept. of Motor Vehicles, Mobile Source Section of Environmental Dept)

PAVED ROADS
Improvements to NEI Method (cont.)

- Perform sampling to refine value used for silt content
  - Only consider if you can collect enough samples to give a good representation of roads in your area
- Obtain and use local precipitation values

  (Source: National Weather Bureau)

UNPAVED ROADS
Overview

- SCC 2296000000
- PM10-PRI/FIL and PM2.5-PRI/FIL
- No condensible material, so:

  PM-PRI = PM-FIL

UNPAVED ROADS
NEI Method

- Activity
  - State level VMT from U.S. DOT, Federal Highway Administration allocated to counties by population
  - Activity Data (VMT on unpaved roads)
  - State-level activity for urban and rural local functional classes

UNPAVED ROADS NEI Method (cont.)

$$Unpaved\ VMT_{Roadtype} = Mileage_{Roadtype} * ADTV * DPY$$

Where:

- Unpaved VMT = road type specific unpaved VMT (miles/year)
- Mileage = total number of miles of unpaved roads by functional class (miles)
- ADTV = Average daily traffic volume (vehicle/day)
- DPY = number of days per year

UNPAVED ROADS NEI Method (cont.)

- Non-local functional classes including:
  - Rural minor collector, rural major collector, rural minor arterial, rural other principal arterial, urban collector, urban minor arterial, and urban other principal arterial
  - ADTV not available for non-local roads, estimated from local urban and rural VMT and mileage

UNPAVED ROADS NEI Method (cont.)

$$ADTV = VMT/Mileage$$

Where:

- ADTV = average daily traffic volume for State and federally maintained roadways
- VMT = urban/rural VMT on county-maintained roadways (miles/year)
- MILEAGE = urban/rural state-level roadway mileage of county-maintained roadways (miles)

UNPAVED ROADS NEI Method (cont.)

- Add Non-local functional class VMT to local functional class VMT to determine State total unpaved VMT by road type
- Unpaved road VMT temporally allocated by month using NAPAP temporal allocation factors for total VMT

UNPAVED ROADS NEI Method (cont.)

- Emission Factor
  - AP-42 emission factor equation

$$EF = [k*(s/12)*(S/30)^{0.5}]/[(M/0.5)^{0.2}] - C$$

Where:

EF	=	size specific emission factor (pounds per VMT)
k	=	empirical constant (1.8 lb/VMT for PM10-PRI, 0.27 for PM2.5-PRI)
s	=	surface material silt content (%)
M	=	surface material moisture content (%)
S	=	mean vehicle speed (mph)
C	=	emission factor for 1980's vehicle fleet exhaust, brake wear, and tire wear

UNPAVED ROADS NEI Method (cont.)

- NEI Default Emission Factor Input Values
  - Surface material silt content(s)
    - Average state-level values developed available at ftp://ftp.epa.gov/EmisInventory/finalnei99ver2/criteria/documentation/xtra_sources/
  - Mean vehicle weight (W)
    - National average value of 2.2 tons (based on typical vehicle mix)
  - Surface material moisture content (M_{dry})
    - 1 percent

UNPAVED ROADS
NEI Method (cont.)

- NEI Default Emission Factor Input Values (cont.)
  - Number of days exceeding 0.01 inches of precipitation (p)
    - Precipitation data from one meteorological station in state used to represent all rural areas of the state
    - Local climatological data available from National Climatic Data Center at http://www.ncdc.noaa.gov/oa/ncdc.html

UNPAVED ROADS
Improvements to NEI

- Summary
  - Review NEI defaults for representativeness
  - Use local data when possible for activity and emission factor inputs
  - If resources are limited, focus on collecting data for:
    - Local precipitation data
    - Local VMT estimates

UNPAVED ROADS
Case Study - Overview

- Case Study: County level emissions inventory for unpaved roads
  - See Case Study Number 7-1

UNPAVED ROADS
Case Study - Solution

- Case Study: County level emissions inventory for unpaved roads
  - See Handout 7-1

CONSTRUCTION
Overview

- SCCs:
  - Residential - 2311010000
  - Commercial - 2311020000
  - Road – 2311030000
- PM10-PRI/FIL and PM2.5-PRI/FIL
  - No condensibles, so PM-PRI = PM-FIL
- 1999 PM2.5-PRI NEI
  - Res - 5%
  - Comm - 40%
  - Road - 55%

RESIDENTIAL CONSTRUCTION
NEI Method

- Activity Data: Number of acres disturbed per year
- Estimated using housing start data
  - Total no. of regional monthly housing unit starts (HS)
  - National monthly housing unit starts available for:
    - 1-unit housing
    - 2-unit housing
    - 3-4 unit housing
    - 5+ unit housing

RESIDENTIAL CONSTRUCTION NEI Method (cont.)

- Regional housing unit starts by housing category estimated as follows:

$$\text{Reg. HS by Category} = \text{Total Reg. HS} \times \frac{\text{National HS by Category}}{\text{Total National HS}}$$

(Reference: *Housing Starts Report, 1999*, U.S. Department of Commerce, Bureau of the Census, Manufacturing and Construction Division, Residential Construction Branch.)

RESIDENTIAL CONSTRUCTION NEI Method (cont.)

- Monthly regional housing starts by housing category summed to obtain an annual total
- County Activity
  - Annual no. of building permits in each county for:
    - Housing structures with 1-unit
    - Housing structures with 2-units
    - Housing structures with 3-4 housing units
    - Housing structures with 5+ units

(Reference: *Building Permits Survey, 1999*, U.S. Department of Commerce, Bureau of the Census, Manufacturing and Construction Division, Residential Construction Branch.)

RESIDENTIAL CONSTRUCTION NEI Method (cont.)

- Regional no. of residential *structure* starts based on the reported no. of housing unit starts:
  - No. of 1-unit housing units = no. of 1-unit housing structures
  - No. of 2 unit housing units divided by 2 units per structure
  - No. of 3-4 unit housing units divided by 3.5 units per structure
  - No. of 5+ unit housing units divided by region-specific units per structure as calculated from building permits data

RESIDENTIAL CONSTRUCTION NEI Method (cont.)

- Estimate county no. of residential structure starts by housing category as follows:

$$\text{County Structure Starts} = \text{Regional Structure Starts} \times \frac{\text{County Bldg Permits}}{\text{Regional Bldg Permits}}$$

RESIDENTIAL CONSTRUCTION NEI Method (cont.)

- Estimated acres disturbed from county no. of structures:
  - 1-unit structures: 1/4 acre per building
  - 2-unit structures: 1/3 acre per building
  - Apartments: 1/2 acre per building
- Estimated duration of construction:
  - 1-unit structures: 6 months
  - 2-unit structures: 6 months
  - Apartments: 12 months

RESIDENTIAL CONSTRUCTION NEI Method (cont.)

- Estimate no. of apartment structures by adding the no. of 3-4 unit buildings and of 5+ unit buildings
- Estimate no. of 1-unit houses with and without basements
  - Multiply regional no. of 1-unit structures by regional percentage of one-family houses with basements and subtract product from total no. of 1-unit houses to estimate 1-unit houses w/out basements

(Reference: *Characteristics of New Houses - Table 9. Type of Foundation by Category of House and Location, 1998,* U.S. Department of Commerce, Bureau of the Census.)

RESIDENTIAL CONSTRUCTION NEI Method (cont.)

- For 1-Unit Housing with Basements
  - Estimate cubic yards of dirt moved per house
    - Multiply assumed 2,000 square feet per structure by assumed average basement depth of 8 feet
    - Add-in 10 percent of above cubic yard estimate to account for footings and other backfilled areas adjacent to basement

RESIDENTIAL CONSTRUCTION NEI Method (cont.)

- 1-Unit Housing with Basements
  - PM10-PRI: 0.011 tons/acre/month plus 0.059 tons/1000 cubic yards of on-site cut/fill
- 1-Unit Housing without Basements and all 2-Unit Housing
  - PM10-PRI: 0.032 tons/acre/month
- Apartments
  - PM10-PRI: 0.11 tons/acre/month
- PM2.5-PRI = 0.2 * PM10-PRI

RESIDENTIAL CONSTRUCTION NEI Method (cont.)

- 1-Unit Structures with Basements

Emissions = (0.011 tons PM_{10}/acre/month) x B x f x m) +

0.059 tons PM_{10}/1000 yards^3 of cut/fill)

where: *B* = no. of housing starts with basements;

f = buildings-to-acres conversion factor (1/4 acre per building);

m = duration of construction activity in months.

RESIDENTIAL CONSTRUCTION NEI Method (cont.)

- 1-Unit Structures without Basements, All 2 Structures, and Apartments

Emissions = (0.032 tons PM_{10}/acre/month) x B x f x m)

where: *B* = no. of housing starts without basements;
f = buildings-to-acres conversion factor; and
m = duration of construction activity in months

RESIDENTIAL CONSTRUCTION NEI Method (cont.)

- Apply a control efficiency of 50 percent for both PM10-PRI and PM25-PRI emissions for PM-10 NAAs; all other areas 0 percent
- Control efficiency represents Best Available Control Method (BACM) controls on fugitive dust construction activities in these counties

RESIDENTIAL CONSTRUCTION NEI Correction Parameters

- Applied to final emissions for all 3 construction categories
- Soil Moisture Level

Moisture Level Corrected Emissions = Base Emissions x (24/PE)

where: PE = Precipitation-Evaporation value for county

- Compiled statewide average Precipitation-Evaporation (PE) values according to Thornthwaite's PE Index

RESIDENTIAL CONSTRUCTION NEI Correction Parameters

- Silt Content

Silt Content Corrected Emissions = Base Emissions x (s/9%)

where: s = % dry silt content in soil for area being inventoried

- County-specific dry silt values are applied to PM10-PRI emissions for each county

RESIDENTIAL CONSTRUCTION Improvements to NEI

- Obtain local data for new construction housing starts, permits for additions/modifications to existing homes

Source: State Housing Agency or Real Estate Association

- Develop a building to acres conversion factor for acres disturbed per construction unit
- Obtain information on seasonality of residential construction practices
- Obtain local information on soil moisture content, silt content, and control efficiency

RESIDENTIAL CONSTRUCTION Case Study - Overview

- Case Study: County level emissions inventory for residential construction
  - See Case Study Number 7-2

RESIDENTIAL CONSTRUCTION Case Study - Solution

- Case Study: County level emissions inventory for residential construction
  - See Handout 7-2

COMMERCIAL CONSTRUCTION NEI Method

- Activity data: No. of acres disturbed per year
- National-Level Activity
  - Dollar Value of Construction Put in Place, 1999
  - National data allocated to Counties

(Reference: *Table 1. Annual Value of Construction Put in Place in the United States for Nonresidential buildings: 1996 - 2000*, Millions of constant dollars, U.S. Department of Commerce, Bureau of the Census.)

COMMERCIAL CONSTRUCTION NEI Method (cont.)

- Allocation of National Data to Counties
  - National level activity allocated to counties using 2 data sources:
    - *Annual Average Employment for SIC 154, Data Series ES202*, Bureau of Labor Statistics, 1999
    - *Annual Average Employment for SIC 154, MarketPlace 3.0*, Dun & Bradstreet, 1999
  - Applied Dun & Bradstreet county proportion of the State total to the BLS State total to estimate employment for counties where data were withheld

COMMERCIAL CONSTRUCTION NEI Method (cont.)

- Activity Data Conversion
  - Converted dollar value to acres disturbed using a conversion factor of 1.6 acres/10^6 dollars applied to the estimated county-level construction valuation data

COMMERCIAL CONSTRUCTION NEI Emission Calculations

- PM10-PRI Emission Factor = 0.19 tons/acre/month
- PM2.5-PRI = 0.2 * PM10-PRI

COMMERCIAL CONSTRUCTION NEI Emission Calculations (cont.)

- Emission formula for calculating the emissions is:

Emissions = (0.19 *tons/acre/month) x $ x f x m*

where: $ = dollars spent on nonresidential construction in millions
f = dollars-to-acres conversion factor
m = duration of construction activity in months (assumed 11 months)

COMMERCIAL CONSTRUCTION Improvements to NEI

- Obtain local information on number of acres disturbed per construction event or per construction dollars spent

Source: Construction Industry Association

- Obtain information on location, average duration, and seasonality of commercial construction practices
- Obtain local information on soil moisture content, silt content, and control efficiency

ROAD CONSTRUCTION NEI Method

- Activity data: Number of acres disturbed
- State-Level Activity
  - Obtained State expenditure data for capital outlay for six classifications
    - Interstate, urban
    - Interstate, rural
    - Other arterial, urban
    - Other arterial, rural
    - Collectors, urban
    - Collectors, rural

(Reference: Highway Statistics, Section IV - Finance, Table SF-12A, "State Highway Agency Capital Outlay - 1999." Federal Highway Administration.)

ROAD CONSTRUCTION NEI Method (cont.)

- State-Level Activity (Continued)
  - Expenditures include all improvement types except for:
    - Minor widening
    - Resurfacing
    - Bridge rehabilitation
    - Safety
    - Traffic operation and control
    - Environmental enhancement and other

ROAD CONSTRUCTION NEI Method (cont.)

- Estimate miles of new road constructed
  - $4 million/mile for interstate roads
  - $1.9 million/mile for other arterial and collector roads

(Reference: Personal Communication with North Carolina Department of Transportation)

ROAD CONSTRUCTION NEI Method (cont.)

- Estimate acres for each road type using estimates of acres disturbed per mile:
  - Interstate, urban and rural; Other arterial, urban - 15.2 acres/mile
  - Other arterial, rural - 12.7 acres/mile
  - Collectors, urban - 9.8 acres/mile
  - Collectors, rural - 7.9 acres/mile

(Reference: *Estimating Particulate Matter Emissions from Construction Operations*, prepared by Midwest Research Institute for U.S. Environmental Protection Agency, 1999.)

ROAD CONSTRUCTION NEI Method (cont.)

- Sum across road types to yield state total of acres disturbed
- Activity Data Allocation to Counties
  - Distributed state-level estimates of acres disturbed to counties according to housing starts
    - see residential construction for description of development of county-level housing start data

ROAD CONSTRUCTION NEI Emission Calculations

- PM10-PRI Emission Factor = 0.42 tons/acre/month
- PM2.5-PRI = 0.2 * PM10-PRI

ROAD CONSTRUCTION NEI Emission Calculations (cont.)

- The formula for calculating emissions is:

Emissions = (0.42 *tons PM10/acre/month) x $ x f1 x f2 x d*

where: $ = State expenditures for capital outlay on road construction
f1 = $-to-miles conversion factor
f2 = miles-to-acres conversion factor
d = duration of roadway construction activity in months (assumed 12 months)

ROAD CONSTRUCTION Improvements to NEI

- Obtain information on location and timing of road construction practices in area

(Source: State Department of Transportation)

- Obtain local data on the number of miles constructed and the number of acres disturbed per project or per mile of road constructed
- Obtain local estimate for duration of projects

ROAD CONSTRUCTION Improvements to NEI (cont.)

- Obtain information on private road construction activity

(Source: Construction Industry Association)

- Obtain local information on soil moisture content, silt content, and control efficiency

ROAD CONSTRUCTION Case Study - Overview

- Case Study: County level emissions inventory for road construction activities
  - See Case Study Number 7-3

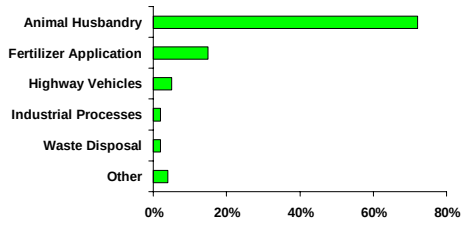
ROAD CONSTRUCTION Case Study -Solution

- Case Study: County level emissions inventory for road construction activities
  - See Handout 7-3

Preparation of Fine Particulate Emissions Inventories

Chapter 8 – Ammonia Emissions from Animal Husbandry

NH3 – Precursor to Ammonium Sulfate & Nitrate (National Emissions ~ 4.8 M TPY)



Update to Ammonia from Animal Husbandry is Timely

- **Inverse modeling** suggests overestimation of ammonia.
- Shortcomings of old NEI
  - Probable errors in emission factor selections, especially for beef.
  - Does not use information on variability of emissions due to different manure handling practices within a given animal industry.
  - Does not make total use of information of available National Agricultural Statistics Service (NASS) data on different animal populations, by average live weight.

Update to Ammonia from Animal Husbandry is Timely (Cont'd)

- **Effluent Guidelines** project provided information on production & waste handling practices (new).
- **National Academy of Science** (NAS) committee recommended a long data gathering effort.
  - **Old NEI estimates** are not the best we can do in the interim (while this data gathering is undertaken).

Improved Basis for Interim NEI Update

- Provides improved data on populations, practices, and emissions.
- Allows a switchover to a process-based framework that is common, transparent and that allows partial updating as more data becomes available.
- Motivates and provide structure for relevant data collection.
- Opportunity to educate users about data limitations, proper use.
- Goal: Higher animal production States will begin to adopt / offer improvements to new method.

Overview of New Estimation Methodology

- Step 1: Estimate average annual animal populations by animal group, state, and county.
- Step 2: Identify Manure Management Trains (MMT) used by each animal group and then estimate the distribution of the animal population using each MMT.
- Step 3: Estimate the amount of nitrogen excreted from the animals using each type of MMT, using general manure characteristics.

Overview of New Estimation Methodology (Cont'd)

- Step 4: Identify or develop emission factors for each component of each MMT.
- Step 5: Estimate ammonia emissions from each animal group by MMT and county for 2002.
- Step 6: Estimate future ammonia emissions for years 2010, 2015, 2020, and 2030.

Step 1: Population Estimates

- Animals: Dairy, beef, swine, and poultry.
  - Keep weight groups & animal types distinct.
- State-level population: 2002 NASS.
- County apportionment: using 1997 Census of Agriculture.
  - Privacy Issue - Where state and/or county is not disclosed, divide equally.

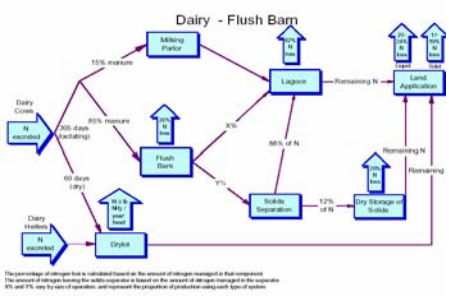
Step 2: Manure Management Trains

- 15 MMT's plus permutations (similar to "model farms" used in past approaches).
  - e.g., Housing, waste storage, land application type.
  - Non-feedlot outdoor confinement (e.g. pasture) is one of the trains for swine, dairy, and beef.
  - MMT's represent different pathways for escape of ammonia to the air.
  - MMT "mix" varies by state, not within a State.
    - Another "opportunity" for improvement

Step 2: Manure Management Trains (Cont'd)

- Animal population, etc. is allocated among the applicable trains.
- Note: Final stage in each train is land application.

Advanced Example of Manure Management Train



Step 3: Nitrogen Excreted

- Typical animal weights (within a type and weight range)
- Nitrogen per 1000 kg of live weight from NRCS *Agricultural Waste Management Field Handbook*
- Local agriculture experts could help improve this
  - Land Grant University Researchers / Extension Agents

Step 4: Emission Factors

- Select the emission factor for each stage of each manure management train.
  - Some are lb/animal, some are percent air release of input ammonia.
  - Both kinds also determine ammonia transferred to next stage.
- Air emissions can never be higher than original manure content.
- Using stage-specific emission factors sets the stage for applying temporal profiles and process-related variability later.

Step 5: Apply for 2002

- Track ammonia release through each manure management train for each animal type, calculating air releases and transfers to next stage.
- Assumes no air emission controls at this time.
  - But can add control assumptions later, and see downstream consequences.
- Emissions are summed up to animal type and county
- Database is preserved with full detail for transparency and later revisions.

Step 6: Future Years Projections

- 2010, 2013, 2020, and 2030.
- USDA and Food and Agricultural Policy Research Institute.
- Accounts for past observed cyclical populations.
- State-by-state population pattern.
  - Changes with time for dairy.
  - Fixed for others.

Comparison of 1999 and 2002 Ammonia NEIs

Animal Group0	1999 NEI			2002 NEI		
	Population	Emission Factor lb/head /yr	Emissions Tons/year	Population	Emission Factor lb/head /yr	Emissions Tons/year
Cattle and Calves Composite	100,126,106	50.5	2,476,333	100,939,728	23.90	1,205,493
Hogs and Pigs Composite	63,095,955	20.3	640,100	59,978,850	14.32	429,468
Poultry and Chickens Composite	1,754,482,225	0.394	345,325	2,201,945,253	0.60	664,238
Total	1,917,704,286	N/A	**3,461,758**	2,362,863,831	N/A	**2,299,199**

Ongoing Additional Improvements

- Plan to incorporate emission estimates for sheep, ducks, goats, and horses.
- Looking at more recent manure production and excretion rates by animal types and weight (may provide lower overall estimates than currently indicated in draft report).
- Looking into ways to better address spatial, seasonal, and regional differences in emissions.

CMU Model and the NEI

- Carnegie Mellon University (CMU) has prepared a model for estimating ammonia emissions from agricultural activities, humans, wastewater treatment, wildfires, domestic and wild animals, transportation sources, industrial activities, and soils.
- Includes an improved methodology for fertilizer application when compared to the methodology used in previous versions of the NEI.
- EPA is evaluating the methodologies used for other source categories in the CMU model.

Preparation of Fine Particulate Emissions Inventories

Chapter 9 – Combustion Area Sources

MANE-VU 2002 RWC Emission Inventory

- Objective
  - Prepare 2002 EI based on survey of household equipment usage and wood consumption patterns
- Survey Method – stratified, random-sampling
- Data Collected for Each Household
  - Wood consumption at equipment level (both real wood and artificial logs)
  - Wood type for real wood
  - Temporal activity to calculate monthly, weekly, and daily emissions

Sample Frame Construction

- Sampling designed to address major sources of variability in activity (i.e., wood consumption)
- Sources of variability include:
  - Location and type of housing
  - Heating demand (expressed as heating degree days (HDDs))
  - Availability of wood

Sample Frame Construction (cont.)

- Sample Stratification
  - Housing Data – 2000 Census tract data used to stratify sample by:
    - Urban, suburban, and rural single-family and "other" homes (other homes = multi-family units such as apartments, condos, mobile homes)
    - Rural category stratified by forested and non-forested areas using USGS GIS data (i.e., Forest Fragmentation Index Map of North America)
  - Heating Demand – Total annual HDDs used to stratify sample into 3 zones

Sample Frame

	Rural-Forested		Rural-Non-Forested		Suburban		Urban	
Geographic Zone	Single-Family	Other	Single-Family	Other	Single-Family	Other	Single-Family	Other
High HDD	Cell 1 61 (173)	Cell 2 61 (64)	Cell 3 61 (87)	Cell 4 61 (66)	Cell 5 61 (61)	Cell 6 61 (72)	Cell 7 61 (69)	Cell 8 61 (69)
Low HDD	Cell 9 61 (150)	Cell 10 61 (62)	Cell 11 61 (118)	Cell 12 61 (69)	Cell 13 61 (76)	Cell 14 61 (67)	Cell 15 61 (75)	Cell 16 61 (62)
Med HDD	Cell 17 61 (87)	Cell 18 61 (60)	Cell 19 61 (91)	Cell 20 61 (64)	Cell 21 61 (71)	Cell 22 61 (60)	Cell 23 61 (63)	Cell 24 61 (68)

Survey Instrument

- Questionnaire developed to gather activity data for:
  - Indoor equipment (fireplaces, woodstoves, pellet stoves, furnaces, and boilers)
  - Outdoor equipment (fire pits, barbeques, fireplaces, and chimineas)
- Pilot survey performed to test the instrument
- Survey conducted using computer-assisted telephone interviewing
  - Completed 1,904 surveys across all 24 cells

Survey Data Reduction/Analysis

- QA reviewed each survey
- Calculated/summarized for each cell:
  - User fraction (fraction of total household population that burns wood in indoor and outdoor equipment)
  - Annual activity (cords of wood by equipment and wood types)
  - Temporal data
- Conducted statistical analyses to identify significant differences between cells for:
  - User fraction
  - Annual Activity

Indoor Wood-Burning Equipment Preliminary Survey Results (% Burners)

Geographic Zone	Rural-Forested		Rural-Non-Forested		Suburban		Urban	
	Single-Family	Other	Single-Family	Other	Single-Family	Other	Single-Family	Other
High HDD	Cell 1 FP= 34 WS= 67 F/B= 21 PS= ***4***	Cell 2 FP= 75 WS= 75 F/B= 0 PS= 0	Cell 3 FP= 43 WS= 76 F/B= 7 PS= 0	Cell 4 FP= 33 WS= 67 F/B= 0 PS= 0	Cell 5 FP= 36 WS= 64 F/B= ***18*** PS= 0	Cell 6 FP= 0 WS= 0 F/B= 0 PS= 0	Cell 7 FP= 80 WS= 30 F/B= 0 PS= 0	Cell 8 FP= 100 WS= 0 F/B= ***50*** PS= 0
Low HDD	Cell 9 FP= 60 WS= 65 F/B= 5 PS= ***2***	Cell 10 FP= 100 WS= 0 F/B= 0 PS= 0	Cell 11 FP= 61 WS= 54 F/B= ***4*** PS= 4	Cell 12 FP= 50 WS= 50 F/B= 0 PS= 0	Cell 13 FP= 70 WS= 35 F/B= 0 PS= 5	Cell 14 FP= 67 WS= 0 F/B= 0 PS= 33	Cell 15 FP= 90 WS= 10 F/B= 0 PS= 0	Cell 16 FP= 100 WS= 0 F/B= 0 PS= ***20***
Med HDD	Cell 17 FP= 55 WS= 66 F/B= 7 PS= 7	Cell 18 FP= 60 WS= 60 F/B= 0 PS= 0	Cell 19 FP= 59 WS= 45 F/B= 0 PS= 9	Cell 20 FP= 100 WS= 0 F/B= 0 PS= ***25***	Cell 21 FP= 81 WS= 27 F/B= ***8*** PS= 4	Cell 22 FP= 50 WS= 50 F/B= 0 PS= 0	Cell 23 FP= 100 WS= 0 F/B= 0 PS= 0	Cell 24 FP= 0 WS= 0 F/B= 0 PS= 0

FP = fireplace; WS = woodstove; F/B = furnace/boiler; PS = pellet stove; Totals do not always add to 100 since some respondents use more than one type of equipment. Values in ***bold italics*** are derived from responses that were identified as wood consumption outliers (equipment could be miss-categorized by the respondent).

Preliminary Results/Observations

- Indoor Equipment
  - Geographic distribution of equipment
    - Rural Areas:
      - Higher diversity of equipment types than in urban areas
      - Higher percentage of stoves and furnaces than in urban areas
    - Urban/Suburban Areas:
      - Lower diversity of equipment types than in rural areas
      - Higher percentage of fireplaces than in rural areas
  - Heating Demand
    - High HDD Zone:
      - Rural Areas – higher percentage of stoves and furnaces
    - Low HDD Zone:
      - Rural Areas – higher percentage of fireplaces

Preliminary Results/Observations (cont.)

- Indoor Equipment
  - For urban areas, it was difficult to find households that burned wood for the sample size taken
  - The urban sample size was not increased because of budget constraints **and** priorities for obtaining a representative sample for three instead of two HDD zones
  - The equipment- and fuel-based survey results were used to estimate emissions (e.g., lb $PM_{2.5}$/household-yr) for each household surveyed
  - A household-based statistical model is being developed to estimate emissions for each cell

Preliminary Results/Observations (cont.)

- Outdoor Equipment
  - Equipment-based emissions will be estimated using survey results

Annual Emissions = Fraction of outdoor equipment users per cell x annual activity x emission factor

Emission Inventory Development

- Emissions were:
  - Estimated for all criteria pollutants/precursors and several dozen toxic air pollutants
  - Estimated at the census tract level (summed to county, State, region)
  - Temporally allocated to support modeling using profiles developed from the survey

Lessons Learned

- Survey Instrument: for regional surveys, tailor it to suit the usage patterns in rural, suburban, urban areas
- Difficult to find wood burners in urban areas – minimum sample sizes need to reflect this

Lessons Learned (cont.)

- For indoor equipment, to keep resources manageable:
  - Consider the use of a statistically-derived emissions-based model (household level) instead of an equipment-specific method
  - Concern: Approach aggregates emissions for different types of wood burning equipment needed to support control measure analysis

Documentation for MANE-VU EI

- Technical memoranda and Work Plan for a Survey to Determine Residential Wood Combustion and Open Burning Activity (July 31, 2001)

  (MANE-VU Web Site: http://www.manevu.org/pubs/index.asp)

How are RWC Emissions Estimated in the '02 NEI?

- SCCs
  - FIREPLACES
    - 2104008001 Without Inserts
    - 2104008002 With Inserts; Non-EPA Certified
    - 2104008003 With Inserts; Non-Catalytic, EPA Certified
    - 2104008004 With Inserts; Catalytic, EPA Certified
  - WOODSTOVES
    - 2104008010 Non-EPA Certified
    - 2104008030 Catalytic, EPA Certified
    - 2104008050 Non-Catalytic, EPA Certified

How are RWC Emissions Estimated in the '02 NEI? (cont.)

- Pollutants
  - PM10-PRI, PM25-PRI, NO_x, CO, VOC, SO_x
  - HAPs (number of pollutants)

Emission Factors for Fireplaces Without Inserts (lbs pollutant/ton of dry wood)

- NO_x, SO_x, VOC, & HAPs
  - AP-42, Chapter 1.9, Table 1.9-1
- PM10-PRI, PM25-PRI, & CO
  - Houck, J.E., et al, "Review of Wood Heater and Fireplace Emission Factors," NEI Conference, May 1-3, 2001
  - Based on test data more current than AP-42
  - PM25-PRI assumed to be same as

Emission Factors for Woodstoves & Fireplaces With Inserts (lbs pollutant/ton of dry wood)

- Criteria Pollutants: AP-42, Chapter 1.10, Table 1.10-1
  - PM10-PRI, PM25-PRI, & CO EFs are average for all woodstoves
  - PM25-PRI assumed to be same as PM10-PRI
- HAPs: AP-42, Chapter 1.10, Tables 1.10-2, -3, & -4
  - AP-42 EFs for Polycyclic Aromatic Hydrocarbons (PAH) reduced by 62% based on recent test data (Houck, et al, 2001)
- Conversion Factor: One cord of wood equals 1.163 tons

Activity Data

- Develop separate national wood consumption estimates for fireplaces with inserts, fireplaces without inserts, & woodstoves to account for:
  - Different emission factors
  - Different usage patterns (climate zones; urban vs. rural)
- National wood consumption estimated using:
  - Number of combustion units
  - Average wood consumption rates
- Spatial allocation of wood consumption to county level performed to reflect usage patterns

Estimating Emissions from Fireplaces Without Inserts

- Step 1: Determine national number homes with usable fireplaces (with and without inserts)
  - Reference: Table 2-25 of 2001 American Housing Survey (AHS) for the United States (U.S. Census Bureau)
- Step 2: Adjust to account for homes with more than one fireplace (multiply Step 1 by 1.17)
  - Reference: 1989 U.S. Consumer Product Safety Commission report

Estimating Emissions from Fireplaces Without Inserts (cont.)

- Step 3: Adjust for fireplaces that burn wood (74% wood, 26% gas)
  - References: Industry trade associations/experts, market surveys (Houck, et al, 2001)
- Step 4: Subtract out fireplaces not being used (42% not used)
  - References: Local surveys, industry market surveys, government publications (Houck, et al, 2001)

Estimating Emissions from Fireplaces Without Inserts (cont.)

- Step 5: Determine number of homes with usable fireplaces with inserts used for heating
  - Used to determine the number of homes with usable fireplaces without inserts
  - Reference: Table 2-4 of 2001 AHS
- Step 6: Adjust to account for homes with more than one fireplace (multiply Step 5 by 1.10)
  - Reference: 1989 U.S. Consumer Product Safety Commission report

Estimating Emissions from Fireplaces Without Inserts (cont.)

- Step 7: Determine number of fireplaces without inserts used for heating and aesthetic purposes
- The amount of wood burned in each device is determined by assuming wood consumption rates
  - 0.656 cords burned /unit/year for fireplaces used for heating
  - 0.069 cords/unit/year for fireplaces used for aesthetics

Estimating Emissions from Fireplaces Without Inserts (cont.)

- In 1997, EPA estimated that 2.94 million cords of wood were burned in the former and 0.483 million cords of wood were burned in the latter

Spatial Allocation of National Residential Wood Consumption to Counties

- National activity is allocated to counties using:
  - Climate zone (i.e., temperature)
  - Demographics/population (i.e., number of single-family homes)
  - Usage patterns for each device (i.e., urban versus rural)

Spatial Allocation of National Residential Wood Consumption to Counties (cont.)

Climate Zone Consumed	Percent of Wood
1 (>7000 HDD)	36
2 (5500-7000 HDD)	19
3 (4000-5499 HDD)	21
4 (<4000 HDD and <2000 CDD)	15
5 (<4000 HDD and >2000 CDD)	9

Spatial Allocation of National Residential Wood Consumption to Counties (cont.)

- Urban/Rural Apportionment
  - Designate each county as either urban or rural, sum activity for climate zone, and adjust county activity so climate zone total matches the following proportions :

	Rural	Urban
Woodstoves	65%	35%
Fireplaces with inserts	43%	57%
Fireplaces without inserts	27%	73%

Estimating Emissions from Fireplaces With Inserts and Woodstoves

- Determine the number of woodstoves and fireplaces with inserts
  - Data obtained from the Department of Census
- Adjust for homes with more than one stove
- Obtain total cords of wood consumed by residential section
  - Energy Information Administration (EIA)
- Adjust for use – heating or aesthetics

Estimating Emissions from Fireplaces With Inserts and Woodstoves (cont.)

- Allocate to climate zones
- Allocate to individual counties
- Sum wood consumption and compare to urban/rural split

Estimating Emissions from Fireplaces With Inserts and Woodstoves (cont.)

- Wood consumption for woodstoves and fireplaces with inserts were apportioned as follows:

Type of Device	Percent of Total Wood Consumption
Non-certified	92
Certified non-catalytic	5.7
Certified catalytic	2.3

Temporal Allocation of Residential Wood Consumption Emissions

- Default temporal allocation profiles by climate zone
  - S/L/T agencies should adjust allocations to better fit seasonal usage patterns
- Seasonal throughput percentages assigned to each climate zone are:

Climate Zone	Winter	Spring	Summer	Fall
5	100	0	0	0
4	70	15	0	15
3	50	25	0	25
2	40	30	0	30
1	33.33	33.33	0	33.33

How Can You Improve the NEI for Your Area?

- Preferred Method: Residential Wood Survey
  - Obtain locally representative information on the amount of wood fuel use specifically for woodstoves & fireplaces (with and without inserts)
  - This will require a local survey, or activity data generated by State & local governments
  - Reduces uncertainties in estimates associated with allocating national activity to counties
- Alternative Method: Census Bureau and EIA Data Method
  - Use if resources are limited or emphasis is on preparing summer season inventory

How Can You Improve the NEI for Your Area? (cont.)

- Rule Effectiveness/Rule Penetration
  - Incorporate effects of S/L/T rules and level of compliance
  - NEI methodology does not account for S/L/T rules

Comparison of MANE-VU Approach to NEI Method

- MANU-VU EI is a bottom-up methodology
- NEI is a top-down methodology
- MANE-VU EI provides for:
  - Better estimates by geographic area (rural, suburban, urban) and census tract (sub-county) level
  - Accounts for differences in housing type (single- and multi-family homes)
  - Better estimates of usage patterns based on HDDs
  - Includes outdoor equipment not included in NEI estimates
  - Provides temporal data

Residential Wood Combustion Case Study - Overview

- Case Study: County level emissions inventory for residential wood combustion
  - See Case Study Number 9-1

Residential Wood Combustion Case Study - Solution

- Case Study: County level emissions inventory for residential wood combustion
  - See Handout 9-1

Residential Open Burning What Sources are Included?

SCCs:

2610030000 - Residential Municipal Solid Waste (MSW) Burning

Pollutants: PM10, PM2.5, CO, NOx, VOC, SO2, 32 HAPs

2610000100 - Residential Leaf Burning

2610000400 - Residential Brush Burning

Pollutants: PM10, PM 2.5, CO, VOC, 6 HAPs

Residential Open Burning NEI Methods for Residential MSW

- Activity Data (tons of waste burned)
- Step 1 - Estimate 2002 rural population by county
  - County-level rural population estimated by applying rural/urban percentages from 2000 Census data to 2002 population
- Step 2 - Multiply per capita waste factor by rural population
  - Used national average per capita waste generation factor of 3.37 lbs/person/day (noncombustibles and yard waste subtracted out).

Residential Open Burning
NEI Methods for Residential MSW (cont.)

- Step 3- Estimate amount of waste burned
  - Assume 28% of total waste generated is burned
- Step 4 - Account for burning bans
  - For counties where urban population exceeds 80 percent of the total population, the amount of waste burned was assumed to be zero, therefore zero open burning assigned to these counties

Residential Open Burning
NEI Methods for Residential Yard Waste

- Activity Data (tons of waste burned)
- Step 1 - Estimate 2002 rural population by county
  - County-level rural population estimated by applying rural/urban percentages from 2000 Census data to 2002 population
- Step 2 - Multiply per capita waste factor by rural population
  - Used national average per capita yard waste generation factor of 0.54 lbs/person/day.

Residential Open Burning
NEI Methods for Residential Yard Waste (cont.)

- Step 3 - Estimate amount of leaf, brush and grass yard waste
  - Multiply total yard waste mass by 25% to estimate leaf waste, 25% for brush waste, and 50% for grass waste
- Step 4 - Estimate amount of waste burned
  - Assume 28% of total leaf and brush waste generated is burned; assume 0% of grass is burned

Residential Open Burning
NEI Methods for Residential Yard Waste (cont.)

- Step 5 - Adjust for variations in vegetation
  - Used the following ranges to make adjustments to the amount of yard waste generated per county:

Percent forested acres per county	Adjustment for yard waste generated
< 10%	Zero out
>=10%, and <50%	Multiply by 50%
>=50%	Assume 100%

Residential Open Burning
NEI Methods for Residential Yard Waste (cont.)

- Step 6 - Account for burning bans
  - For counties where urban population exceeds 80 percent of the total population, the amount of waste burned was assumed to be zero, therefore zero open burning assigned to these counties.

Residential Open Burning
NEI Methods for Residential MSW and Yard Waste

$$E = A * EF * (1 - CE * RP * RE)$$

where: E = Controlled Emissions, lbs pollutant per year
A = Activity, tons of MSW or leaves/brush burned per year
EF = Emission Factor, lbs per ton burned
CE = % Control Efficiency/100
RP = % Rule Penetration/100
RE = % Rule Effectiveness/100

- 100% CE assumed for counties where urban population exceeds 80% of the total population
- Assumed 100% RE and RP
- All other counties, assumed 0% CE, RE, and RP

Residential Open Burning EIIP Alternative for Yard Waste

- Identify records of burning permits or violations, coupled with data (or assumptions) on typical volumes and material composition

Residential Open Burning Improvements to NEI Methods

- Review EIIP Volume III, Ch. 16 Open Burning
- Obtain State/local estimates of per-capita waste generation
- Use State/local estimates for amount or percentage of waste burned
- Obtain State/local estimates of months when yard wastes are burned

Residential Open Burning Improvements to NEI Methods (cont.)

- Sources
  - Solid Waste Agency
  - Air Agency
  - Health Department
  - Solid Waste Management Organization
  - Local Survey

Residential Open Burning Improvements to NEI Methods (cont.)

- Identify rules prohibiting or limiting open burning, and the organization that enforces those rules
- For areas that have burning prohibitions, consider performing rule effectiveness (RE) surveys
- Level of enforcement/compliance can be a significant variable in calculating controlled emissions
- Rule penetration (RP) to reflect duration of seasonal bans relative to annual activity profile, exempt activities

Residential Open Burning MANE-VU Example

- Development of 2002 residential open burning inventory for MANE-VU States
- Multi-state RPO developed inventory following EIIP procedures

Residential Open Burning MANE-VU Example (cont.)

- Developed survey instrument to collect:
  - Number/percentage of households that burn waste
  - Burn frequency
  - Amount per burn
  - Seasonal Activity
- 3 separate surveys for:
  - Residential MSW
  - Brush
  - Leaf

Residential Open Burning MANE-VU Example (cont.)

- Survey results were used to estimate emissions for each survey jurisdiction
- For non-surveyed areas, default activity data derived from survey responses were applied

Residential Open Burning MANE-VU Example (cont.)

- To estimate the mass of waste burned for residential MSW and yard waste, the following equation was used:

$$Wt = HH * Bt * M$$

where: Wt = Mass of waste burned per time period
HH = Number of households that burn
Bt = Number of burns per time period
M = Mass of waste per burn

Residential Open Burning MANE-VU Example (cont.)

- Developed control database to establish area-specific control efficiency (CE), rule effectiveness (RE), and rule penetration (RP)
- Performed rule effectiveness (RE) survey to determine level of compliance with state or local open burning prohibitions
- To estimate default RE values, the survey data was statistically analyzed resulting in one value for all non-surveyed areas

Residential Open Burning MANE-VU Example (cont.)

- Emissions estimated for all criteria pollutants/precursors and several toxic air pollutants
- Emissions estimated at the census tract level (summed to county, State, region)
- Emissions temporally allocated to support modeling using profiles developed from the survey

Lessons Learned

- If leaf burning is significant, perform separate surveys in targeted areas for leaf waste and brush waste burning
- Perform MSW surveys separate from yard waste surveys, instead of combined to reduce survey length
- A larger sample may have allowed for greater geographic distinction

Lessons Learned (cont.)

- Sub-county emissions estimates serve as the basis for a more spatially refined inventory
- Regional survey provides greater consistency
- Better accounting of controls results in decreased emissions relative to NEI

Land Clearing Debris Burning What Sources are Included?

SCCs:

2610000500 - Land Clearing Debris Burning

Pollutants: PM10, PM 2.5, CO, VOC, 6 HAPs

Land Clearing Debris Burning NEI Method

- Activity Data
- Estimate the county-level total number of acres disturbed by residential, non-residential and roadway construction
  - Used number of acres disturbed from fugitive dust construction emissions activity calculations
- Apply loading factor to number of acres to estimate the amount of material or fuel subject to burning

Land Clearing Debris Burning NEI Method (cont.)

- Weighted, county-specific loading factors developed based on acres of hardwoods, softwoods, and grasses (BELD2 data base in BEIS)
- Multiplied average loading factors by percent contribution of each type of vegetation class to the total county land area

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Land Clearing Debris Burning NEI Method (cont.)

- Average loading factors for hardwood and softwood further adjusted by 1.5 to account for mass of tree below the surface

Fuel Type	Fuel Loading (tons/acre)
Hardwood	99
Softwood	57
Grass	4.5

Land Clearing Debris Burning NEI Method (cont.)

- Fuel Loading Factor Equation

$$L_w = F_h * L_h + F_s * L_s + F_g * L_g$$

where: L_w = County-specific weighted loading factor
F_h = Fraction of county acres classified as hardwoods
L_h = Average loading factor for hardwoods
F_s = Fraction of county acres classified as softwoods
L_s = Average loading factor for softwoods
F_g = Fraction of county acres classified as grasses
L_g = Average loading factor for grasses

Land Clearing Debris Burning NEI Method (cont.)

- Emission Calculation

$$E = A * LF * EF$$

where: E = Emissions, lbs pollutant per year
A = No. of acres of land cleared per county (residential + commercial + road construction)
LF = County-specific loading factor, tons per acre
EF = Emission factor, lbs pollutant per ton

- Represents an upper-bound emissions estimate
- Assume all fuel loading on land cleared is burned; no controls or bans

Land Clearing Debris Burning Improvements to NEI Method

- Review EIIP section on Open Burning
  - EIIP Volume III, Ch. 16
  - Preferred methods rely on direct measure of mass of waste or debris burned
  - Mass amounts may be available from permits issued
- Improve estimates of the acres cleared
- Develop improved estimate of the “average loading factor”

Land Clearing Debris Burning Improvements to NEI Method (cont.)

- Identify specific counties with burning bans, and specification of counties where wastes are burned
- State or local estimates of the percentage or amount of waste burned per construction event

Land Clearing Debris Burning Northern Virginia Example

- Performed RE survey to determine the level of compliance with rules for:
  - Land clearing debris burning
  - Residential waste burning
- Developed RE to apply to ozone season open burning emission estimates for the Virginia portion of the Washington DC-MD-VA Ozone Nonattainment Area

Land Clearing Debris Burning Northern Virginia Example (cont.)

- Reviewed conditions of existing open burning rules
  - Time period of ban
  - Exemptions and special provisions
- Surveyed local open burning officials responsible for tracking and enforcing open burning rules

Land Clearing Debris Burning Northern Virginia Example (cont.)

- Started with EPA questionnaire from RE guidance, modified for open burning
- Responses to questions are assigned specific point values that add up to a maximum of 100 points, considered equivalent to a RE percentage value

Land Clearing Debris Burning Northern Virginia Example (cont.)

- RE values analyzed by county and for 5-county region
  - Estimated regional RE of 93 percent
- If area comprised of counties and jurisdictions with significantly different population densities, analyze responses by urban and rural areas

Lessons Learned

- Local officials may defer to higher officials (e.g., county or state-level) for enforcing open burning rules
- RE may be high for time period that ban is in effect, but need to account for duration of ban (RP) if less than annual or seasonal
- It is important to account for when the ban is taking place

Agricultural Burning - Overview

- SCC 2801500000
- PM10-PRI and PM2.5-PRI
- Both condensibles and filterables

Agricultural Burning - General Method

- Activity
  - Acres of crop burned
- Loading Factor (tons of biomass or vegetation per acre burned)
- Emission Factor
  - Pounds $PM_{2.5}$ per ton of vegetation burned (crop-specific)

Wheat Stubble Burning Example

- Method **-** Develop inventory using county-specific data when available
  - Activity
    - Acres of wheat burned by month obtained from burn permits issued by county fire department
    - Fuel loading for wheat stubble from county agricultural extension office

Wheat Stubble Burning Example (cont.)

- Emission Factors
  - PM10: 8.82 pounds per ton of wheat stubble burned
  - PM2.5: 8.34 pounds per ton of wheat stubble burned
- Resolution
  - Spatial – county
  - Temporal – monthly

Wheat Stubble Burning Example (cont.)

- Sample Calculation
  - PM2.5-PRI Emissions
    - = Acres Burned per month * Loading Factor * Emission Factor

Annual PM2.5-PRI Emissions = $\sum$ Monthly Emissions

Agricultural Burning - Improvements

- Preferable to inventory larger fires (> 100 acres) as events with a start and stop date and time; lump smaller fires into monthly acreages
- Requires coordination with burners and permit authorities
- Start building a system and relationships with the burners/ permitting authorities to enable such an inventory in the future

Agricultural Burning - Improvements (cont.)

- Obtain local acres of crops burned data from:
  - Burn permits
  - Survey of county agricultural extension offices
- Verify that burns actually occurred
- Obtain fuel loading data
  - Local data preferred from county agricultural extension offices, local Natural Resources Conservation Service Center
  - National defaults available from Chapter 2.5 in *AP-42*

Agricultural Burning Case Study - Overview

- Case Study: County level emissions inventory for burning of wheat stubble
  - See Case Study Number 9-2

Agricultural Burning Case Study - Solution

- Case Study: County level emissions inventory for burning of wheat stubble
  - See Handout 9-2

Overview of Wildland Fire Inventory

- Wildland Burning
  - Types: Wildfires, Managed (Prescribed) Burns
  - Burners:
    - NPS, USFS, BLM, USFWS, State & Tribal Forests, Private burners
- Prescribed Burning
  - Habitat improvement
  - Managing undergrowth and understoring of the forest
  - Reducing risk of wildfires

How were Wildfire Emissions Estimated in the '99 – '02V1 NEI?

- Pollutants
  - PM_{10}, $PM_{2.5}$, NO_x, CO, VOC, SO_2, 30 HAPS
- Emission Factors (AP-42)
- State-specific fuel consumed per acre burned
- Annual Activity Data ~ State (or regional) level
  - USFS, BIA, BLM, NPS, FWS
  - Some States provide private / State burn data
  - Spatial allocation to counties using forested area
- Emissions Processor ~ Allocates Diurnal & Monthly

What are the RPO's Doing?

- The Regional Planning Organizations (RPOs) are working on:
  - Treating most fires as point sources
  - Using fire-specific fuel consumption
  - Providing a much improved emission estimate

What are Future Plans for Improving the Approach to Estimating Fire Emissions?

- Future plans include the following:
  - Incorporate satellite observations
  - Improve locational data
  - Improve fuel characterization
  - Use actual fire weather conditions that effect emissions

What Needs to Happen Nationally / Regionally to Improve Wildland Fire Emissions?

- Improve Regional / National Databases & Models
  - Fire Event: area burned, when, where
  - Develop, refine national & regional models & databases to estimate pre-burn fuel loading
  - Refine, expand use of fuel consumption models
  - Provide guidance on estimating impact of mitigation measures on emissions

What Needs to Happen Nationally / Regionally to Improve Wildland Fire Emissions? (cont.)

- Fire Events Database Development
- Federal MOU
  - Includes: EPA, DOI, USDA
  - Broad Scope: Fire Management Activities
  - Status: In Progress
- Investigation of the role of national databases
  - USDA / DOI efforts
  - NEISGEI http://capita.wustl.edu/NEISGEI/
  - B-RAINS (Pacific NW Database)
  - Much more work is needed to move toward real time data collection, QA & sharing

What Needs to Happen Nationally / Regionally to Improve Wildland Fire Emissions? (cont.)

- Investigating the Potential Use of Satellites
  - EPA
    - EIIP-funded Overview of Using Satellites in AQ
      - http://www.epa.gov/ttn/chief/eiip/pm25inventory/remsens.pdf
    - Collaboration w/ NASA
  - Interagency
    - NIFC
    - Work at Missoula Fire Research Center & Salt Lake City
    - Collaboration w/ NASA
  - Others
    - CAMFER

What Needs to Happen Nationally / Regionally to Improve Wildland Fire Emissions? (cont.)

- Emission Estimation Tools & Inventories
  - EPA
    - Recent Report: Fire Emission Estimation Methods
  - USFS
    - Work at the Fire Sciences Lab (Missoula)
    - Work at Pacific NW Research Station (Corvallis)
  - Collaboration
    - WRAP - Fire Emissions Joint Forum
    - RPO-led 2002 Wildland Fire EI development
    - Nat'l Fire Emissions Workshop
    - Nat'l FCC coverage @ 1 km2 resolution
    - Emissions model to interface with grid models

Wildland Fire Emissions Module (under development)

- Modular input to Emission Models (e.g., SMOKE, OpEM) to interface with the CMAQ modeling system
- User Inputs: Fire locations, duration, size
- Model Components (Modules from the BlueSky system)
  - Fuel loading default: NFDRS / FCC map
  - Fuel Moisture: Calculates using MM5 met data
  - Fuel Consumption: CONSUME / FOFEM
  - Emissions, Heat Release & Plume Rise: EPM & Briggs (modified)

Wildland Fire Emissions Module (under development) (cont.)

- Outputs: Gridded hourly emissions, plume characteristics
- Integrate, Test & Release Module (late 2004)